RECONSTRUCTION AND EXTENSION OF THE MÉRICOURT LOCKS: STUDY OF THE HYDRAULIC OPERATION OF THE STRUCTURE

Authors: Gwenaëlle CHEVALLET, Chloé CHENE, Antoine HALBARDIER, Franck RANGOGNIO
RECONSTRUCTION AND EXTENSION
OF THE MÉRICOURT LOCKS:
STUDY OF THE HYDRAULIC OPERATION OF THE STRUCTURE

Smart Rivers 2019 Conference / September 30 – October 3, 2019
Outline of the presentation

- General introduction
- Context and objectives of the project
- Methodology
- Results
Outline of the presentation

- General introduction
- Context and objectives of the project
- Methodology
- Results
The dimensioning of a lock and the definition of the associated lock management instructions are complex problems that have been addressed to this day using:

- Either scaled physical models sometimes heavy to implement,
- Or generally:
  - 1D transient hydraulic studies,
  - 3D steady-state hydraulic models centered on the filling and emptying valve elements,
  - application of charts or simplified calculation approaches for mooring problems,
  - feedback from operators.
General introduction

The BRLingénierie teams have implemented a methodology to answer all these questions in a computational and combined way through transient 3D-CFD hydraulic modelling (using Flow-3D© software developed by Flow Science).
Outline of the presentation

- General introduction
- Context and objectives of the project
- Methodology
- Results
The Méricourt locks are located 60 km downstream of Paris. They allow the passage of 10,000 ships per year. There are two functional locks of 185 m and 160 m capacity.
Context

Project of renovation and extension of the Méricourt locks aims to rebuild the existing locks as they present visible structural disorders. The project owner takes advantage of this project to:

- Extend the 160 m lock n°1 in order to standardize the capacity of the locks,
Context

• Change the emptying system for a lock from aqueducts to 18 valves on the door
Context

• Install floating bollards on the renovated locks
Main objectives

- Building of a 3D-CFD hydraulic model of the lock
- Modelling of the floating bollards and the boats
- Respecting management instructions:
  - Filling/emptying times (<15 min)
  - Tension in the mooring lines (300 kN max.)
  - Water slope (<1‰)
Methodology

The model presented here concerns the project situation of lock n°1 (L=185 m, w=17 m). This model includes:

- **3D lock geometry** designed with dedicated tools (Autodesk Revit™ and Allplan™)
Methodology

- **3D-CFD transient hydraulic model**
- **Moving objects:**
  - Coupled to the fluid:
    - Grand Rhénan type boat (ECMT class Va, L=110 m, w =11.4 m, capacity 1500 to 3000 tons),
  - Floating bollards,
  - Respecting management instructions: upstream aqueduct gates or downstream valves.
- **Mooring line module** linking the boat to the bollards,
- **Collision module** between the boat and the lock walls.
Methodology

- **Model**: about 500,000 mesh elements

- **Computation costs**: associated calculation times to simulate a filling or emptying of the lock (real time of 10 to 15 minutes) are between approximately 6 h and 12 h

- **Computation routines**: BRLi developed computation routines that specifically address the problems encountered (Flow-3D© code is partially open)
Methodology

- Coupling 1D and 3D transient hydraulic modelling, using an iterative process
Test and validation phases:

- **Consideration of floating bollards** (iterative process to find a compromise concerning the density of the bollards to avoid oscillations or too large inertia)

- Number, characteristics and positions of the mooring lines
Methodology

Tests and validation phases:
• Loading level of boats/barges, type of convoys

Grand Rhénan type: 110m length, 11.4m width, 4.7m height (ECMT class Va)

Convoy: 185m length, 11.4m width, 4.7m height

Complex Rhénan geometry:
Methodology

Tests and validation phases:

- Instructions for filling or emptying management

Opening rates of the gates
Methodology

• First focus on a filling of future lock n°1 (185 m x 17 m)
Results

Once the boundary conditions implemented (forebay and tailbay water levels) and the characteristics of the vessel and the mooring plan chosen, the model implemented made it possible to meet the following points:

- **Duration of a filling or emptying** cycle for given management instructions,
- **3D hydraulic conditions** of the flows in the lock (mainly velocity distribution),
- **Efforts transmitted in the bollards** during a filling or emptying cycle.
Results

Forces on the mooring lines
Possibility to optimize the filling or emptying management instructions - i.e. the laws governing the opening of the valves – in order to:

- Ensure compliance with the maximum forces in the bollards (250 to 300 kN per bollard [25 to 30 tons]),

- Minimize the duration of the locking times (about 10 to 11 minutes) while respecting the material constraints of the valve components.
Results (example with a complex boat geometry)

Temps = 0s
Discussion

3D-CFD modelling was so far limited for its implementation in navigation structures by the absence of moving objects coupled or not to the movements of the fluid and the absence of specific mooring modules.

The 3D model used made it possible to answer all the problems related to locking with a single tool:

- emptying/filling time
- hydraulic loads
- forces on the boat
- forces on floating bollards
- …
Results comply with all orders of magnitude calculated using charts, simplified methods or based on the operator’s feedback (emptying/filling laws, flow coefficients of the valves, maximum forces on the bollards, etc.)

The forces on the bollards (essential dimensioning parameters) sensitive to:

- obviously the filling laws,
- but also to the free length of the mooring lines and their rigidity as well as to the general mooring plan (number and position of mooring lines).
Discussion

Areas for improvement identified:

- Possibility to control the operating instructions of the valves using water levels, speeds…
- Calibration of the model on observed in situ data (even if the modelling results respect all orders of magnitude from the literature or the operator’s feedback)
Thanks for your attention

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PERFORMANCE OF A LOCK WITH VERTICAL LIFT GATES AFTER RENOVATION: Case study including measurements and optimisation of leveling system

Author: Johannes J. VELDMAN (Aktis Hydraulics)

Co-authors: Remco BERENTSEN (RWS)
Marius A.C. DAM (Aktis Hydraulics)
Outline of presentation

1. Lock Delden in the Twentekanaal
2. Upgrade of the Twentekanaal
3. Lock Delden: renovation and levelling time
4. Levelling system and modelling
5. Measurements and model calibration
6. Reengineering (gate lifting schedule)
7. Implementation and results
8. Conclusions
9. Additional remarks
1a. Twenthekanaal (1933)

Construction:
- Class IV (1500 Tons)
- 3 locks - vertical lift gates

Main inland waterway, annually:
- 10,000 - 15,000 vessel
- 5 - 10 M.Tons
- 100,000 TEU

Now congestion:
- Maintenance & Upgrade
- Class Va/M8 (2700 Tons)
1b. Lock Delden: renovation and levelling
1c. Contracts: construction and renovation

1932: Construction of a complete lock

2018: Mowing the grass near the lock
2. Renovation

Phase 1: West (Class Va)
- Canal (completed)
- 2nd Lock Eefde (under construction)

Phase 2: East
- Canal (in preparation)
- Lock Delden (Renovation 2018)

After: Increased levelling time!
3a. Lock Delden: Overview

Designed in the early 30-ties
- L = 133 m, B = 12 m and 6 m lift
- Vertical lift gates
- Levelling: lift gates

Performance:
- New lift gates (1994)
- 6,000 - 8,000 vessels/year;

Renovation in 2018:
- Replace: mechanical and electrical parts
- Prepared for Class Va (safety)
3b. Lock Delden: 2018

Renovation of the lock:
- Navigation interrupted;
- Lock chamber (inspection);
- Lift gates (paint);
- Mechanical parts (renewed);
- Electric motor (renewed);
- New lock operation / control system.

Approach / objective:
- Reproduce gate lifting scheme:
  - Levelling time equal: increase not allowed!
3c. Lock Delden: Increased levelling time

After renovation:

- Skippers complained (gut feeling, summer 2018);
- Levelling time from measurement (2017) (on vessel entry and departure speed for Class Va (Pianc-WC, 2018).
- Video (2018): 1 to 3 min extra.

The gut feeling was right!

Decision to analyse the levelling time (desk study, measurements, etc.)

First step (August 2018):

- Log data from lock operation system
3d. Lock Delden Data (14 Aug 2018)

Log data from lock operation system

Filling: 19 min
1 to 6 min longer

Emptying 17 min:
4 to 7,5 min longer
till gate fully open
3e. Lock Delden: Plan for desk study

1. Data collection:
   - Drawings of lock and levelling system
   - Gate-lifting schedules
   - Levelling times

2. Measurements of lock filling:
   - level in lock and position of gates

3. Simulations with the LockFill program (developed by RWS & Deltares)
   - discharge, level in lock and force on vessel
4a. Levelling: Slow lifting lift gates

Levelling:
- Very slow lifting of gates

Dissipation:
- Bottom ripples
- Stilling basin

133 m long lock chamber
4b. Levelling: Upper gate with stilling basin

Levelling system (1932):
- Scale model 1:30
- Constant lifting speed (5 mm/s)

Tranquillity in lock:
- Stilling basin
- Flow deflection sheet

Levelling opening:
- Slit between gate and sill;
- Slit width controlled by the deflection sheet
4c. Levelling: Simulation of levelling process

LockFill simulation:
- Discharge
- Level in lock
- Forces on vessel

IN
- Lock dimensions,
- Levels
- Vessel
- Levelling opening
- Gate lifting schedule

LockFill option:
- Lift gates
  (developed for similar lock Eefde)

OUT
- Time series of:
  - Opening,
  - Discharge,
  - Level in lock,
  - Forces on vessel.
4d. Levelling: Comparison with measurements

Lift speed: 0.0048 m/s
Gate lifting schedule:
• 0.2 m (wait 30 s)
• 0.5 m (wait 270 s)
• 1.20 m
• Δh <0.1 m: Final opening

Bad fit!
➢ Systematic deviations
5a. Calibration: Flow guiding sheet

Drawings:
- 2018 renovation:
  - sharp corner
  - 10 mm slit

- 1994 new gate:
  - Sharp corner
  - 50 mm slit

- 1933 original:
  - Round corner
  - 50 mm slit
  - S-shape sheet
5b. Calibration: System & Schedule

Flow guiding:
- Drawings not up to date;
- Flow guiding: different shapes
- Sill is rounded (≠ drawing);

Lifting schedule:
- Lifting steps: 0.03 m higher;
- Waiting periods: 3 sec longer;
- Water level: inaccurate;
- Final opening: delayed.
5c. Calibration: prototype measurement

Log data from lock:
- Irregular spaced in time
- Moving average with limited accuracy (0,01 m)

Prototype measurements (21/22 Feb 2019)
Time series of water level (1 Hz, 1 mm accuracy):
1. Outer harbour (Upper)
2. Lock chamber (Upper lock head)
3. Lock chamber (Lower lock head)
4. Outer harbour (Lower)
5d. Calibration: water level

Log data and accurate level data

Log data from lock system:
- Logged at 10 mm interval;
- Different levels with open gate;
- Sudden jumps (0.1 m);
- Not continues (2 m jump);
- 100 s moving average (50 s delay).

Concl.: Not reliable for gate opening
5e. Calibrated levelling model (LockFill)

Calibration:
- Guiding sheet
- Gate lifting schedule

Verification:
- Three other gate lifting schedules
6a. Reengineering

  - Levelling slower than designed (1933)?
- Variable lifting speed (2018):
  - Lifting schedule without stops possible!
- Hydraulic force on the flow guiding sheet:
  - Upward force < 50 kN.
- Upgrade Class IV $\rightarrow$ Class Va:
  - Relative force in the lock < 0.85%.
- Final opening delayed by time lag and inaccurate levels:
  - Allow fully opening at head < 0.3 m.
6b. Reengineering: develop lifting schedule

Develop optimal gate lifting schedules:
- Tool: calibrated LockFill model;
- Design conditions;
- Knowledge: waves, resonance;
- Levelling step by levelling step;
- Trial and Error;
- Etc.

Result: reengineered schedules for filling and emptying.
7a. Reengineered gate lifting: Filling

Filling:
In 12 min lock gate fully open
2 to 5.5 min faster
7b. Force on the vessel: Filling

Filling:
Max force:
0.9 %

0.4 % lower
7c. Reengineered gate lifting: Emptying

Emptying:
In 8.5 min
lock gate fully open
2 to 4.5 min faster
8a. Summary

- Renovation of gate lifting system (April 2018).
- Lifting system reproduced (May 2018).
- Skippers noticed: unexpected slower locking (June 2018).

Actions (>July 2018):
- Analysis: old documents, measurements, LockFill-model
- Reengineering of lifting schedule: faster locking (April 2019)
- New schedule implemented (12 sept 2019)
- Monitoring new schedule (> October 2019)
8b. Conclusion: main results

The new lifting schedule reduces:
- Locking: 2 to 5 minutes
- Longitudinal force: 30%

The lock Delden:
- Extra locking capacity of 10% to 25%
- Criteria for Class Va
8c. Conclusions: Lessons learned

Renovation:
- Renewing gate (1994): interferes with original levelling system;

Information:
- Historic information basis to maintain performance;
- Accurate measurements for earliest final opening of gates.
9. Recommendations & remarks

• Analyse the lock levelling system should be performed prior to the renovation;
• Final opening of gate: to be based on accurate level info;
• Level in the lock: to be based on both ends of lock chamber;
• An “end of levelling” ring might be used to attend the lock operator that that gate can be fully opened.
• Technical (electro-mechanic) innovations allow reengineering of the gate lifting schedule and accelerate the locking process.
Thank You

Questions?
CHALLENGES IN THE DESIGN AND CONSTRUCTION OF THE NEW LOCK IN TERNEUZEN

A SPECIAL DUTCH - FLEMISH COLLABORATION

Authors:

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Flemish Government, Dept Mobility and Public Works, Division Maritime Access, Belgium
Overview of presentation

1. Existing situation
2. New Lock: size, location, scope
3. Project organization / Contract
4. Major Challenges (cultural, technical)
5. Design and lay-out (challenges)
6. Construction and phasing (challenges)
Situation - topography

Bottleneck on the Rotterdam-Paris waterway
Lock complex overview

Western lock (1968)
- tonnage 80,000 dwt

Middle lock (1910)
- tonnage 10,000 dwt

Eastern lock (1968)
- inland vessels only

65,000 transits/Year
- Inland Shipping 53,000
- Sea Going Vessels 9,000
- Recreational 3,000

Situation at Terneuzen before project start
Why a new lock?

Basically:

• To reduce the waiting times (especially inland vessels)
• Growing number of vessels
• Larger vessels
• End of lifetime Middle lock
The New Lock – size, scope

- Dimensions: L 427m W 55m, draft 14.5m (New Panamax size)
- 4 rolling gates
- 2 bascule bridges

Also:
- Enlarged lock approaches
- Up to date sea flood defence
- Road connection over the locks
Challenge: Project complexity

- Location
- Functions
- Hindrance

5 year construction period lock complex remains operational
International context: Netherlands-Belgium-EU

Minister Flanders
Minister Netherlands

Flemish - Dutch Scheldt Commission

Steering Committee

Project Team

Joint Venture

CEF contribution (vh TEN-T)
Many common things:
• Neighbours, history, language
But yet...
• Flemish vs Dutch language sometimes know a different meaning of words, which can be confusing
• Differences in building culture, based on history and ...  
  > Construction methods
  > Types of structures
  > Type of contracts
• Organization culture
Some more facts

- Legal Mandator = The Netherlands (Ministry - Rijkswaterstaat)
- Budget/Finance: Flanders 80% - The Netherlands 20%
- Total budget Project: € 934 mln
<table>
<thead>
<tr>
<th><strong>Contract</strong></th>
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<tbody>
<tr>
<td><strong>Scope</strong></td>
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<tr>
<td><strong>Contract:</strong></td>
</tr>
<tr>
<td><strong>Type:</strong></td>
</tr>
<tr>
<td><strong>Date of start</strong></td>
</tr>
<tr>
<td><strong>Completion</strong></td>
</tr>
</tbody>
</table>

**Joint Venture**

- Sassevaart
- Demec
- Van Laere
- Contractors
design issues in preparation

- Dimensions of the lock
- Position of the lock
- Flood protection (climate)
- Discharge capacity
- Filling/Emptying system, lockage time
- Type of lock gates and number of gates per lockhead

Others decisions:
- Durability (100 years lifetime)
- Mooring facilities, jetties, fenders
- Plan spatial quality (esthetic)
- Sustainability (zero energy lock)
3D/4D Model > helps to solve design and construction challenges

- Design
- Clash detection
- Operation/maintenance
- As build
3D/4D Model - 2

- Clash detection
- Operation /maintenance
Hawser forces

- **Situation:**
  - Max head 5.07m
  - Max lev time 20 min

- **Challenges**
  - Mooring forces
  - Density currents (Salt)

- **Choosing F/E system**

- **Scale Model tests**
Hawser forces -2

Solution:

- Bottom filling system
- using floor grids
- 1 side longitudinal culverts
- Prescribed by principal
- Verification of final design by physical model studies
Construction challenges

- Ongoing traffic by waterway and by road
- No damage to existing infrastructure (deformation, vibrations)
- Continued flood defense during construction
- Safety (most important)
- Limited space
- Functioning of the lock (many different integrated processes)

Requires:
- Clever construction techniques
- Smart Phasing and Logistics
Construction challenges

- Boom Clay, water impermeable
- Ancient gully, open connection
- Land subsidence in 1960s never again
Realizing New Lock Terneuzen in 1 minute
Phasing of the project: Preparation
Phasing of the project: New Lock

Lock finished
Phasing of the project: **Finishing**

End situation

**Nieuwe Sluis Terneuzen in gebruik**

(new text)
Construction techniques
Diaphragm walls

- Principles
- Need of this technique
- Complexity and former issues
- Approach

**Principle of diaphragm wall construction**

1. Excavate with concrete as a support fluid
2. Place the opening
3. Pour concrete
Diaphragm walls – 2 (Approach)

To guarantee a good quality:

- Both contractor and principal closely monitor design, preparation and construction.
- A test panel has been built in actual conditions
- Results have been used for optimalization of process.
Summary

New lock of Terneuzen is a Bi-National project, where the best technologies and experiences from both the Netherlands and Flanders are combined.

Complex project:
- One of the largest locks in the world
- Multiple functions combined on one spot
- Also during construction phase
- Challenging conditions
- Challenging technologies
Thank you for your attention!

https://www.youtube.com/watch?v=KaUVB_q03WA

Project New Lock Terneuzen

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PINNOVATIVE TECHNOLOGY SAVES 100-YEAR OLD PANAMA CANAL LOCKS

Author: Thomas Stephens
TenCate Geosynthetics
The 1907 US Design for The Panama Canal
SS Ancon first ship to transit the Panama Canal Aug. 15, 1914
Gatun Locks
Atlantic Entrance
Scour Location

5.0m – 7.0m
Miraflores Locks Southwest Wing Wall
Miraflores Locks Southwest Wing Wall
The Culprit
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
The Solution
80 Ton / 50m3 Sand Filled Geobag Unit
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit

Pump Concrete Grout Into Scour Area Thru Holes Bored In Bottom Slab

Geobag® Underwater Retaining Structure
The Solution
80 Ton / 50m³ Sand Filled Geobag Unit

Pump Concrete Grout Fill Scour Area Under Slab

Geobag® Underwater Retaining Structure
Gatun Locks Dividing Wall Repair Design
Gatun Locks Dividing Wall Repair Design

Bottom Eroded Elevation: -15.24 m

Original Bottom Elevation: -15.24 m
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
East Side Chamber Looking North
The Solution
90 Ton / 50m³ Sand Filled Geobag Unit
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit
The Solution
90 Ton / 50m3 Sand Filled Geobag Unit
To Date More Than 500 of the 90 Ton Geobag Units Have Been Installed Around All Three Sets of Panama Canal Locks
CONCLUSIONS:

• Innovative Solutions Require A Multidiscipline Collaborative Approach

• Geobag Containers Allowed for Rapid Response and Deployment

• Geobag Containers Were Flexible Enough to Conform to The Irregular Eroded Bottom of The Canal

• Geobag Containers Had The Mass to Not Be Moved When Subjected to High Velocity Water Flow or Prop Wash.

• Geobag Containers Performed as the Underwater Coffer Dam to Retain the Concrete Pumped Under The Canal Lock Structures

• Geobag Containers Are Performing as Long Term Weighted Erosion Control Mattresses
INNOVATIVE DESIGN OF HYDRO-FLOATING SHIP LIFT WITH LIFT WEIGHT OF KILOTON

Author: Xue Shu, Guo Chao, Hu Ya'an, Li Zhonghua

Nanjing Hydraulic Research Institute
1. Introduction

2. Study on Optimization of Hydrodynamic Driving System

3. Design of Hydro-floating Ship Lift with Lift Weight of Kiloton

4. Simulation calculation of hydraulic characteristics of Yantan HFSL

5. Conclusions
1. INTRODUCTION

Hydro-floating ship lift is a new type of ship lift invented by Chinese engineers in 2000’s. It has advantages of reliable operation, high efficiency, simple structure and convenient maintenance.
Hydro-floating ship lift has high-level safety standard. Once the load of chamber changes, the draught of counterweight will automatically adjust and the integral system will balance again. So, it has obvious advantages in dealing with security problems such as chamber leaking.
1. INTRODUCTION

Jinghong Hydro-floating ship lift (Mekong river)
The design principle of an equal inertial F/E system is that the inertial length from the inlet to each outlet is equal. From the point of view of geometric structure, the branch pipeline is completely symmetrical.
When this type of hydraulic driving system is applied to engineering, the water flow is not completely smooth before the diversion, and there will be a bias phenomenon which may affects the next diversion.
1. INTRODUCTION

to meet the requirement of equal inertial length between the inlet and the outlet, the number of vertical shafts and counterweights of “independent shaft + equal inertial F/E system” must be $2^n$. This limitation is very inconvenient for the arrangement of the lifting point of the ship chamber and affects the stress and deformation of the chamber.
1. INTRODUCTION

With the development of economic, ship lift with lift weight of kiloton has become the inland navigation trend.
When the dimension of ship chamber increased, the size and number of counterweights and shafts of hydro-floating ship lift will increase correspondingly. The overall layout of ship lift, the synchronization and stability of the shafts’ water level under the condition of large flow rate become technical problems that need to overcome.
In order to improve the hydraulic characteristics, a new type of hydraulic driving system which is suitable for hydro-floating ship lift with lift weight of kiloton is presented.
After water filling valve, the main culvert is divided into two branches and leads to the culverts under the vertical shafts on the left and right respectively. Ports are arranged along the top of the culvert from which the water flows into the shaft. In order to reduce the disturbance of the countweights caused by the jet flow at the top of culvert, the energy dissipator is arranged above the culvert ports for further rectification.
Yantan hydro-floating ship lift is designed for 2×1000t barges, and the maximum lifting height is 70m. The effective water area of the ship chamber is 150m×12.1×3.4m. Dead weight of chamber structure and its equipment is 4300t. Chamber speed in the air is 10.0 m/min. It is proposed to set 14 lifting points on the both sides of the chamber, with a drum diameter of 4600mm and length of 4400mm.
### 3. DESIGN OF HYDRO-FLOATING SHIP LIFT WITH LIFT WEIGHT OF KILOTON

#### Jinghong hydro-floating ship lift (500t)

<table>
<thead>
<tr>
<th>Name</th>
<th>Jinghong shiplift</th>
</tr>
</thead>
<tbody>
<tr>
<td>River</td>
<td>Langcanjiang River</td>
</tr>
<tr>
<td>Lift height</td>
<td>66.86 m~46.10 m</td>
</tr>
<tr>
<td>Lifting time</td>
<td>17 min</td>
</tr>
<tr>
<td>Chamber</td>
<td>--</td>
</tr>
<tr>
<td>Weight (including water)</td>
<td>2920 t</td>
</tr>
<tr>
<td>Usable dimensions</td>
<td>58.0m×12.0m×2.5m</td>
</tr>
<tr>
<td>DWT of Vessels</td>
<td>500 t</td>
</tr>
<tr>
<td>Type of F/E system</td>
<td>A dynamically balanced system with 16 manifolds</td>
</tr>
<tr>
<td>Filling/Emptying Valves</td>
<td>3×Φ1.6m</td>
</tr>
<tr>
<td>Shaft</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>28</td>
</tr>
<tr>
<td>Cross section</td>
<td>Φ2.5m</td>
</tr>
<tr>
<td>Weight</td>
<td>28,000t</td>
</tr>
<tr>
<td>Cross section</td>
<td>Φ7.7m</td>
</tr>
</tbody>
</table>

#### Yantan hydro-floating ship lift (2×1000t)

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Design parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight of counterweights</td>
<td>( \Sigma F_b = 27500 \text{t} )</td>
</tr>
<tr>
<td>Diameter of counterweights</td>
<td>7.5m</td>
</tr>
<tr>
<td>Effective height of counterweights</td>
<td>( H_{bu} = 15.12 \text{m} )</td>
</tr>
<tr>
<td>Total height of counterweights</td>
<td>20.06m</td>
</tr>
<tr>
<td>Diameter of shaft</td>
<td>7.7m</td>
</tr>
<tr>
<td>Water consumption for F/E operation</td>
<td>( V_{max} = 46645 \text{m}^3 )</td>
</tr>
<tr>
<td>Sectional dimension of F/E System</td>
<td>3.6m×4.0m (length×width)</td>
</tr>
<tr>
<td>Sectional area of F/E System</td>
<td>14.4m²</td>
</tr>
<tr>
<td>Max water velocity in main culvert of F/E System</td>
<td>( v = 9.96 \text{m/s} )</td>
</tr>
<tr>
<td>Number of culvert ports at each tower</td>
<td>14</td>
</tr>
<tr>
<td>Size of culvert ports</td>
<td>2.0m×0.27m×1.5 (length×width×height)</td>
</tr>
<tr>
<td>Total area of culvert ports</td>
<td>( \Sigma \omega_b = 15.12 \text{m}^2 )</td>
</tr>
<tr>
<td>Diameter of culvert valve</td>
<td>2.5m</td>
</tr>
<tr>
<td>Total area of culvert valve</td>
<td>( \Sigma \omega_l = 14.73 \text{m}^2 )</td>
</tr>
</tbody>
</table>
4. SIMULATION CALCULATION OF HYDRAULIC CHARACTERISTICS OF YANTAN HFSL

**basic equations**

**continuity equation:**
\[
\frac{dh_f}{dt} = \frac{A_s}{A_{j\beta} - A_{f\beta}} \cdot u - \frac{A_p}{A_{j\beta} - A_{f\beta}} \cdot \frac{dh_f}{dt}
\]

**motion equation:**
\[
\frac{d^2 h_f}{dt^2} = \lambda h_s - \lambda h_f + \beta
\]

**energy equation:**
\[
H_u = h_s + \frac{1}{2g} \left( \frac{dh_s}{dt} \right)^2 \pm \frac{\epsilon}{2g} u^2 \pm \frac{L_p}{g} \frac{du}{dt}
\]

**mathematical simulation model**

- Continuity equation:
  \[
  \frac{dh_f}{dt} = h_x
  \]

- Motion equation:
  \[
  \frac{du}{dt} = \frac{g}{L_p} \left( H_s - h_i - \frac{1}{2g} \left( \frac{dh_i}{dt} \right)^2 \right) - \frac{\epsilon}{2g} \frac{u^2}{L_p}
  \]

- Energy equation:
  \[
  \frac{dh_x}{dt} = \lambda h_s - \lambda h_f + \beta
  \]

- Comparison between the measurement values and the numerical simulation values.
When filling valve opens in 120s and the chamber goes down, the maximum flux of the F/E system is $143m^3/s$. And the average velocity of ship chamber is $0.17m/s$ (10.2m/min). The descending operation time of the ship lift is approximately 550s. In addition, the discharge coefficients of filling system is 0.31.
When emptying valve opens in 120s and the chamber goes up, the maximum flux of the F/E system is 140m$^3$/s. And the average velocity of ship chamber is 0.16m/s (9.6m/min). The ascending operation time of the ship lift is approximately 630s. The discharge coefficients of emptying system is 0.38.
5、CONCLUSIONS

1) It is reasonable and feasible to choose hydro-floating ship lift scheme for Yantan expansion project.

2) The discharge coefficients of filling and emptying system are 0.31 and 0.38, respectively.

3) According to the one-dimensional mathematical model of optimized hydrodynamic driving system for Yantan ship lift, when the filling and emptying valve opens in 120s, the ascending and descending operation time of the ship lift is approximately 630s and 550s. And the maximum flux of the F/E system is 140m$^3$/s and 143m$^3$/s respectively. The total water consumption is about 46645m$^3$. 
RENOVATION WORKS ON LOCKS AND CONTINUATION OF SHIPPING: IMPACTS ON STRUCTURES STABILITY

Alexandre DORADOUX
BRLingénierie
Locks and ship lift design

Renovation works on locks and continuation of shipping: impacts on structures stability

A. Doradoux
SMART RIVERS
October 2, 2019
Outline of the presentation

- Context and objectives of the paper
- Lock of Gambsheim: Study of external stability
- Lock of Denain: Study of internal stability
- Conclusion and considerations for future works
Outline of the presentation

- Context and objectives of the paper
- Lock of Gambsheim: Study of external stability
- Lock of Denain: Study of internal stability
- Conclusion and considerations for future works
Context

Voies Navigables de France (VNF) has engaged a restauration policy of the french waterway network:

- To secure the service levels
- To modernize some of his fluvial structures such as locks

In the same time, VNF has to face:

- The increasing of the number of users
- The important social-economic impact of a lock closure
Problematic

Draining periods of the locks are sometimes not sufficient to realize the entire rehabilitation works

- Continuation of shipping during works
- New project situations and specific operating conditions appear
  Never studied before during historical dimensioning
Objectives of the paper

- Presentation of the normative context which can be used for structure calculations
- Illustrate the impact of dimensioning on works methods
Outline of the presentation

- Context and objectives of the paper
- Lock of Gambsheim: Study of external stability
- Lock of Denain: Study of internal stability
- Conclusion and considerations for future works
Lock of Gamsheim: Study of external stability
Lock of Gamsheim: Study of external stability

1) Earthwork
2) Armoured trench wall

“Lightened” lock wall
Alternating of full and empty lock chamber
Lock of Gambsheim: Study of external stability

2 methods were used:
- **Eurocode 7** (and specifically NF-P-97-281)
- **CFBR recommendations** (*French Committee of Dams and Reservoirs*)

<table>
<thead>
<tr>
<th>EC7</th>
<th>CFBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Overturning verification (excentricity)</td>
<td>- Crack opening state</td>
</tr>
<tr>
<td>- Slip resistance</td>
<td>- Shear resistance state</td>
</tr>
<tr>
<td></td>
<td>- Compressive resistance state</td>
</tr>
</tbody>
</table>
Lock of Gambsheim: Study of external stability

**EC7 – Overturning verification:**

\[ 1 - \frac{2 \times e}{B} \geq \frac{1}{2} \quad \text{(Serviceability Limit State)} \]

With:
- \( e \): excentricity of vertical load (\( F_v \)) in relation to the middle of the block
- \( B \): width of the block
CFBR – Crack opening state:

\[ \sigma'_N(x') = - \frac{f_{tk}}{\gamma_{mft}} \]

With:
- \( f_{tk} \): characteristic tensile strength of material
- \( \gamma_{mft} \): partial factor
- \( \sigma'_N \): upstream stress of the block

In Serviceability Limit State, we admit a maximum crack opening of **25% of the block width**

Iterative method in which we consider full uplift under the cracked area
Lock of Gambsheim: Study of external stability

**Results:**

<table>
<thead>
<tr>
<th>État limite d'extension des fissures CFBR</th>
<th>Vérification excentrement ELS EUROCODES</th>
<th>CAS 3: Nappe à +127 NN + SAS VIDE</th>
<th>CAS 4: Nappe à +127 NN + SAS PLEIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Valeur admissible</td>
<td>1/2</td>
<td>1-2e/B</td>
</tr>
<tr>
<td>Elément 1 (= bloc supérieur)</td>
<td>0,5000</td>
<td>1,31</td>
<td>2,62</td>
</tr>
<tr>
<td>Elément 2</td>
<td>0,5000</td>
<td>1,062</td>
<td>2,124</td>
</tr>
<tr>
<td>Elément 3</td>
<td>0,5000</td>
<td>0,857</td>
<td>1,714</td>
</tr>
<tr>
<td>Elément 4</td>
<td>0,5000</td>
<td>0,764</td>
<td>1,528</td>
</tr>
<tr>
<td>Elément 5</td>
<td>0,5000</td>
<td>0,614</td>
<td><strong>1,228</strong></td>
</tr>
<tr>
<td>Elément 6 (= bloc inférieur)</td>
<td>0,5000</td>
<td>0,503</td>
<td><strong>1,006</strong></td>
</tr>
</tbody>
</table>

**Safety factor**

\[ \Gamma = 1 - \frac{2e}{B} \]

\[ \Gamma = \frac{25\%}{% \text{ calculé}} \]

Vérification particulière menée par ailleurs (*hors article*)
Lock of Gamsheim: Study of external stability

Results:

<table>
<thead>
<tr>
<th>Etat limite d'extension des fissures</th>
<th>Valeur admissible</th>
<th>CAS 3 : Nappe à +127 NN + SAS VIDE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Elément 1 (= bloc supérieur)</td>
<td>25,00</td>
<td>10,23</td>
<td>8,19</td>
</tr>
<tr>
<td>Elément 2</td>
<td>25,00</td>
<td>10,22</td>
<td>8,19</td>
</tr>
<tr>
<td>Elément 3</td>
<td>25,00</td>
<td>10,22</td>
<td>8,19</td>
</tr>
<tr>
<td>Elément 4</td>
<td>25,00</td>
<td>10,22</td>
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</tr>
<tr>
<td>Elément 5</td>
<td>25,00</td>
<td>10,22</td>
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</tr>
<tr>
<td>Elément 6 (= bloc inférieur)</td>
<td>25,00</td>
<td>10,22</td>
<td>8,19</td>
</tr>
</tbody>
</table>

Vérification particulière menée par ailleurs (hors article)

- Full lock chamber: upper blocks less stable
- Empty lock chamber: lower block less stable
- Regardless of the normative context, the case with empty lock chamber is always the most unstable
- EC7 SLS is the most limiting condition
Outline of the presentation

- Context and objectives of the paper
- Lock of Gambsheim: Study of external stability
- Lock of Denain: Study of internal stability
- Conclusion and considerations for future works
**Lock of Denain: Study of internal stability**

**Expansive slag to change**

**Dimensioning scenario:**
- Central island terraced ("Lightened" lock wall)
- Continuation of shipping (full lock chamber)
Lock of Denain: Study of internal stability

Finite Element Modeling:

Bottom lock wall and top concrete slab foundation are logically stretched
Lock of Denain: Study of internal stability

Comparison with historical reinforcement drawings:

- Lack of reinforcement in the bottom of lock wall
- But the residual tensile stresses are compatible with the allowable tensile stresses in the concrete

Importance to study each scenario, even those corresponding to the work period

It could have an impact on works methods (installation of struts, earthwork phasing more restrictive,...)
Outline of the presentation

- Context and objectives of the paper
- Lock of Gambsheim: Study of external stability
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- Conclusion and considerations for future works
Conclusion and considerations for future works

During the design phase:
- Importance to study all the possible scenario
- To ensure the technical feasibility of the project within these particular operating conditions
Conclusion and considerations for future works

Comparison between EC7 and CFBR is not so obvious:

- Both methods need different Limit State (even though some similarities exist)
- CFBR results depend on the choice of the partial factor and intrinsic characteristics at the interface between blocks
- Limit conditions are more or less drastic depending on the method
- CFBR method is very precise (iterative calculation) but mainly focuses on dam structures
Conclusion and considerations for future works

However, calculation philosophies remain similar and these two methodologies can be combined in order to get as close as possible to the real physical phenomena that we can observe on these ancient works to rehabilitate
Thanks for your attention
OPERATION OF A MONITORING SYSTEM INCLUDING FIBER OPTICS ON THE RHINE LEVEES BETWEEN STRASBOURG AND IFFEZHEIM

Authors: Cyril GUIDOUX
Jean-Robert COURIVAUD & Fanny DUBIE
Vincent SPEISSER
1. Introduction
   a. Context
   b. Description of the levees

2. Surveillance system
   a. Design
   b. Measurement devices

3. Data analysis
   a. Methodology
   b. Routine analysis

4. Real-time monitoring
   a. Tigger point and surveillance supervision
   b. Detections and visual inspections
Context

- mid-2007: VNF launches a diagnostic and instrumentation project for the canalization dikes on the left bank of the Rhine at the Gambsheim and Iffezheim reaches
- 2010: Project management entrusted to the SAFEGE / EDF / geophyConsult group
- 2013-2014 Installation of the system
Purpose of the surveillance system

• provide information to the Owner both on the long term and in near real time during the hazard on the hydraulic behavior of the structures

• piezometric measurements in the structure and in the downstream toe: evaluation of the saturation lines

• water level measurements in the Rhine: upstream hydraulic load

• temperature measurements: location of leaks within the structure or its foundation
Description of the levees

- Instrumented structures
  - from PK 296,320 to 309,200: 13.5 km of levee on left bank of Gamsheim reach,
  - from PK 309.2 to 334: 26 km of levee on left bank of the Iflezheim reach
  - dividing dam separating the Ill and Rhine downstream from the Gamsheim locks

- Composition of dikes (1974)
  - Sand/gravel embankment with silty core, resting on a thin layer of silt and then on sand/gravel alluvial deposits.
  - maximum height 10 m
  - width at the top 5.5 m
  - slope from 1/2.5 to 1/2
Design of the surveillance system

- EDF-geophyConsult methodology
  - 2D thermo-hydraulic simulation of the structure
  - modelling of a leak-alike anomaly within the structure
  - application of EDF models for processing raw data leak temperature

leak detected?
Measurement devices

• Distributed temperature measurements
  o optical fiber installed in a shallow trench (1 m to 1.5 m deep) dug along the downstream dike toe
  o leaks into the core or at the embankment-foundation interface (flow rate ≥ 1l×min-1×m-1) should be detected
Measurement devices

• Water level (piezometer and Rhine river)
  o 64 monitored piezometer
  o 4 locations for Rhine water level

• Data acquisition
  o one measurement per hour
  o Measurements uploaded daily by radio or GSM to the control room at Gambsheim’s lock
  o real time backup on a sftp server feeding the geophyConsult database, on which the processing methods are then applied

Smart Rivers / Lyon 2019 / B7_2
Methodology

- preprocessing of data, (matrix formatting, corrections, expression of measurements according to PK, division into homogeneous sections)

- data analysis to detect signal singularities by (mainly statistical analysis AJOUT): detection parameter
Routine analysis

• detection criterion:
  o fixed value, measured during in situ tests of artificial leaks (1 liter/minute/m)

• characterization of the phenomenon observed were the singularities are detected:
  o nature of the temporal evolution of the detection parameters?
  o could the results be caused by a phenomenon other than a leak?
  o are time series of temperature data compatible with a leak phenomenon?

• cross-checking with field observations (visual inspections, other auscultation measurements)
Real-time monitoring

• Trigger point
  o Rhine flow above 2 100 m3/s at the Kehl-Kronenhof gauging station
  o confirmation required by the Owner

• Occurrences
  o from 02/02/2016 to 21:00 to 02/02/2016 at 05:00
  o from 13/05/2016 at 14:15 to 17/05/2016 at 16:00
  o from 04/06/2016 at 17:00 to 01/07/2016 at 17:00
Surveillance supervision

- At least twice a day:
  - download and processing of auscultation data (raw temperature measurements, piezometric measurements and Rhine level measurements)
  - interpretation of the auscultation data and analysis of the hydraulic behavior of the dikes
  - feedback to the client

- 48 hours after real-time monitoring is lifted:
  - post-event visual inspection

- During the following two weeks:
  - weekly auscultation

---

Manpower
- 104 hours of work in working days and daytime hours,
- 55 hours of night work and weekend work
Detections

- Gambsheim
  - Detection parameter < detection criterion
  - Atypical behavior on portions of the dykes comprising crossing structures near which passes the optical fiber

*The presence of these structures induces temperature variations unrelated to the hydraulic loading of the dike*

Detection parameter from PK 296.3 to PK 298.9 during the June 2016 flood
• Iffezheim
  
  o Detection parameter < detection criterion
  o Several peaks appeared along the Mole and risberme on the left bank of the River III, as well as on the Offendorf harbor bypass dike

Detection parameter from PK 309 to PK 311.2 during the June 2016 flood
• Gambsheim
  - Ill in flood → Dike toe where the optical fiber is installed was submerged of 20 to 50 cm of water.
  - Detection peaks correspond to the infiltrations of the water of the Ill in the dike toe
• Iffezheim
  - Offendorf harbor bypass dike: the Rhine level was high enough to flood the usually dry upstream dike toe by 20 to 40 cm of water
  - detection peaks correspond to local infiltration of the Rhine water into the structure and/or the rise of the local aquifer, without any consequence for the structure
Conclusion

1. tool successfully used in the Gambsheim and Iffezheim reaches since 2015

2. monitoring in real time the state of the dikes during the floods of 2016 → very satisfactory inventory of the behavior of structures during exceptional hydraulic loadings

3. all events detected by the monitoring system were confirmed by field elements

4. real-time monitoring organization relevant to the objectives set by the contracting authority

5. AJOUT leaks detection method was implemented in situation of long-term periodic monitoring and flood monitoring → well adapted to these different monitoring situations

6. qualification for flood monitoring to be consolidated with greater experience feedback
... thanks you for your attention ...

... and is looking forward to listening to your questions ...
Contacts

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Website
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DEF-PATHOLOGY IN CONCRETE SUPPORTING A LOCK-GATE: USE OF NUMERICAL MODELLING TO RE-ASSESS STRUCTURAL BEHAVIOUR

Jean-François Seignol, Ifsttar
François Spataro, Cerema
Didier Germain, Cerema
Laurent Labourie, Cerema
Pierre-Yves Scordia, VNF
• The structure and its pathology
• Global strategy of the study
• Numerical model for DEF-affected structures
• Application to the beam supporting the lower gate
• Conclusion
Prestressing:
Horizontal: 122 x STUP 12\(\Phi 8\) cables at ca. 0.56 MN/cable (56 t/cable)
Vertical: 22 x STUP 12\(\Phi 8\) tendons at ca. 0.52 MN/cable (52 t/cable)
Cracks caused by internal swelling reactions

SEM-observation of delayed ettringite in concrete sample

SEM-observation of ASR-gel in concrete sample
What is DEF?

- Internal swelling reaction due to late ettringite formation
- \( \text{SO}_4^{2-} + \text{C3A} \rightarrow \text{Ettringite} \)
- Free sulfates in cement paste due to high temperature (> 65 °C) during hydration process
- Casting massive structures => high temperature due to hydration heat

(Divet, 2003)
Consequences of DEF

- Swelling of the concrete
- Cracking inducing loss of mechanical properties

(Baghdadi et al., 2008)
• The structure and its pathology
• **Global strategy of the study**
• Numerical model for DEF-affected structures
• Application to the beam supporting the lower gate
• Conclusion
Global strategy of the study

- Technical committee started in 2016
- To understand and assess problems affecting downstream head of the lock
- Serviceability and structural safety
- To assist VNF (structure manager) in its management policy and for modernization / enlargement projects
Available data

- Deformation monitoring
- Concrete sample analysis (2012 and 2018)
- In-situ investigations (crosbow test for cable tension, permeability of concrete...)
Role of numerical model

- Assess present and future state of the beam and its cables (tension)
- Input for global model of the lock (forces due to beam swelling)

Global 3D-model of the lock (credit: ISL Ingénierie)
• The structure and its pathology
• Global strategy of the study
• **Numerical model for DEF-affected structures**
• Application to the beam supporting the lower gate
• Conclusion
DEF in Cesar-LCPC

Three steps:

1. Early-age: assessing temperature in concrete
2. Swelling potential: function of temperature history
3. During life-span: swelling of concrete (chemo-mechanical coupling)
Assessing early-age temperature

Heat equation in concrete

\[
\begin{align*}
C_v \frac{\partial T}{\partial \tau} &= -\text{div}\mathbf{q} + l \frac{\partial \alpha_h}{\partial \tau} \\
\mathbf{q} &= -K \text{grad} T
\end{align*}
\]

Cement hydration rate (Arrhenius equation)

\[
\frac{\partial \alpha_h}{\partial \tau} = A(\alpha_h) \cdot \exp \left( -\frac{E_h}{RT} \right)
\]

Initial conditions (fresh concrete temperature)

\[
T(\tau_0) = T_{\text{ini}}
\]

\[
\alpha_h(\tau_0) = 0
\]

Boundary conditions (Ambient temperature and convection through free surface or form)

\[
\mathbf{q} \cdot \mathbf{n} = -h_e(T_e - T)
\]

(Tailhan et al., 2010)
Swelling potential as a function of thermal history at early age

\[ \varepsilon_\infty = \dot{\varepsilon}_m \int_{T_0}^{T_F} f(T(\tau)) d\tau \]

\[
\begin{cases} 
  f(T) = 0 & \text{if } T \leq T_0 \\
  = \exp \left( -\frac{E_a}{RT - T_0} \right) & \text{else}
\end{cases}
\]

(Baghdadi et al., 2008)
Chemo-mechanical model

Free chemical swelling

$$\varepsilon_{\chi}(t) = \varepsilon_\infty \frac{1 - \exp(-t/\tau_c)}{1 + \exp(\tau_l/\tau_c - t/\tau_c)}$$

Global strain incl. chemical swelling

$$\varepsilon = \varepsilon_e + \varepsilon_c + \ldots + \varepsilon_{\chi}$$

Consequence of micro-cracking

$$E = E_0(1 - d(\varepsilon_{\chi}))$$

new time step

(Seignol et al., 2012)
• The structure and its pathology
• Global strategy of the study
• Numerical model for DEF-affected structures
• **Application to the beam supporting the lower gate**
• Conclusion
Finite element model

ca. 21,000 nodes
ca. 97,000 tetrahedron elements

(Casting #5 is upstream beam)

Casting #6
Casting #4
Casting #3
Casting #1

≈ 25 m
≈ 3 m
≈ 9 m
Early-age temperature

For each casting step:
- 3 days btw. concreting and form removal
- 11 days before next casting

Convection:
- $h_e = 7.29 \text{ W/m}^2/\text{°C}$ if form
- $h_e = 9.72 \text{ W/m}^2/\text{°C}$ else

Air temperature:
Daily variation between $T_{\text{min}}$ and $T_{\text{max}}$ (from monthly means by Météo-France)
Zones where \( T > 65 \, ^\circ\text{C} \) in each casting (Threshold for DEF risk)
Chemo-mechanical coupling

Boundary conditions: built-in in the lock walls

Load: weight, prestressing in x and z directions

Parameters for DEF-expansion: standard values (not yet fitted to monitoring results)

Deformation after 50 years
• The structure and its pathology
• Global strategy of the study
• Numerical model for DEF-affected structures
• Application to the beam supporting the lower gate

• Conclusion
• Large lock affected by DEF in the beam supporting the downstream gate
• DEF due to high temperature at early-age (hydratation heat)
• Numerical model to assess consequences of DEF in the beam:
  ▶ Deformations
  ▶ Tensions in prestressing cables
  ▶ Forces/displacements transmitted to other parts of the lock
• DEF-model still needs to be fitted
Next step

Residual exp. test \( \rightarrow \) partial fit. \( \rightarrow \) Swelling parameters \( \rightarrow \) Numerical simulation \( \rightarrow \) Deformations in structure \( \rightarrow \) Compare \( \rightarrow \) Monitoring

(Li et al., 2004)
(Seignol et al., 2016)
References


• (Li et al., 2004) : Li, K.; Coussy, O. & Larive, C. Modélisation chimico-mécanique du comportement des bétons affectés par la réaction d'alcali-silice -- Expertise numérique des ouvrages d'art dégradés. Laboratoire central des ponts et chaussées, 2004

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• (Seignol et al., 2016) : Seignol, J.-F.; Boldea, L.-I.; Leroy, R. & Godart, B. Numerical Model Applied to the Reassessment of the Serviceability and Safety of AAR-affected Power-plant in 15th Int. Conf. on Alkali-Aggregate Reaction in Concrete, Sao Paulo, Brazil, 2016.

BIM for hydraulic infrastructures: the benefits of an approach involving project management, exploitation and engineering

Authors: Franck Rangognio – BRL Ingénierie
Julien Vanwarreghem – BRL Ingénierie
Outlines of the presentation

- Introduction
- BIM contribution to navigation structures
- New working methods for the Project Managers
- Improving reliability of deliverables for Project Owners
- Management tool for Operators
- Bim constraints
- Conclusion
Introduction

- For over 60 years, BRL group jointly worked on ownership, the project management and operation of numerous hydraulic structures.

- First needs for BIM appeared at the contracting authority to develop a heritage database, for management and maintenance purposes.

- It was then applied to design phases of pumping stations of BRL group hydraulic network.
BIM was implemented within the engineering teams, over increasingly diversified hydraulic infrastructures like treatment plants, water tanks, water towers …
... and applied to navigation infrastructures like dams, locks, quays, canal bridges...

BIM shows many advantages for the different actors involved in navigation infrastructures projects...
1. **Interaction management** between different specialized offices:
   - A single support for common quality approach
   - Contractual management of responsibilities in terms of production …

BIM approach was used for the *Public Private Partnership* for the reconstruction of 29 dams on the Aisne and on the Meuse rivers.
New working methods for the Project Managers

2. Optimization of production times: digital models show a real advantage through:
- Standardization of repetitive works
- Parameterization of the equipments

It allowed optimization of those equipments to be standardized for every dam of the project (29).
3. **Interoperability between different tools** used during study phases: structure dimensioning and hydraulics for example.

3D parametric models were used for the study of the reconstruction of the Méribourt locks on the Seine river.
Improving reliability of deliverables for Project Owners

BIM delivers a guarantee of the quality of various deliverables:

- Improving the reliability of estimated costs
- Reducing approximations of 3D modelling of the structures
- Detailed elaboration of the realization phases and associated schedules
Improving reliability of deliverables for Project Owners

The extension project of the *Quesnoy-sur-Deûle* lock in Nord-Pas-de-Calais required very precise and complex phasing of the work. The phasing required a 3D reasoning in space and in time to limit the facility's unavailable periods to a minimum.
Improving reliability of deliverables for Project Owners

BIM enabled:

- Reliable measurements of provisional and final works to be carried out
- Easier identification of constraints for each of the construction phases
- Detailed lists of costs and estimated quantities from numerical model
- Planning based of the numerical model
Management tool for Operators

**Easy access** to archives, maintenance and management informations.

55 parking spots on large gauge network in Nord-Pas-de-Calais: interactive tool integrating all the plans and technical instructions for a standardised parking area accessible.
Added to the financial investments for the tools themselves, BIM process requires, from:

- The Project Manager: Technical formations and recruitment of dedicated skills (BIM manager)

- The Project Owner: formation or external work from BIM specialists to define precisely the needs and specifications as well as their costs.

- For Operators: being able to access a numerical model but also making it evolve for the life duration of the project, as well as coupling with Computer Assisted Management Tools
Conclusion

Unlike BIM is well spread in the building industry for many years, BIM is still not widely used in France in the field of navigation infrastructures.

Efforts from software developers to be compatible with modelling tools specific to the sector and interest from actors in the sector foreshadow a wider use of BIM for navigation structures and possibly the next standard in the future.
A FRENCH EXPERIENCE OF STRUCTURAL HEALTH MONITORING OF SCOUR AFFECTING RIVER INFRASTRUCTURES

Frédérique Larrarte, Franziska Schmidt, Edouard Durand, Arnaud Bontemps, Yannick Della Longa, Mark Cheetham, Sidoinie de la Roque, Mohsen Hosseinghalian, Christophe Chevalier - IFSTTAR, LHSV, CEREMA, SNCF, Cofiroute, Railenium
Scour: a world wide risk

Main bridge failure causes in the USA between 1989 and 2000
(K. Wardhana & F.C. Hadipriono, 2003)

Major consequences for transport networks
(Rivière St Etienne, La Réunion, photo Cerema)
SSHEAR: A national project

Task 1: Management, coordination and development

Task 2: "Model" approach
Experiments & numerical modelling

Task 3: "Field" approach
Site characterisation and monitoring

Task 4: Application by managers and end-users
Experimental site selection

based on several criteria related to:
• representative sites on which scouring phenomena have been observed and are in progress,
• hydraulic-meteorological-geographical context,
• documented sites for which data are available (geometry, type of support, inspection and monitoring report, bathymetric, geotechnical, hydraulic data, etc.),
• rules and regulations.

Photos Cerema & IFSTTAR
Instrumentation for continuous monitoring:

- water level, (1 or 3D) velocity profile, and sediment level or bathymetry.
- For each measurand:
  - the min-max measuring range,
  - the desired characteristics (uncertainties, resolution,...),
  - intrusiveness,
  - innovative techniques / more robust techniques,
  - homogeneity of a fleet of equipment
  - equipment acquisition costs,
  - operating and maintenance costs,
  - data recovery costs,
  - on-site deployment constraints,
  - installation constraints,
  - power supply (mains, battery, if batteries what autonomy...),
  - post processing (validation criteria, operation ,...).
Abutment site hydrology

- 2015 - 2016
- 2016 - 2017
- 2017 - 2018
- 2018 - 2019

Photos IFSTTAR

Agust 2018

January 2018
Bed evolution determination

\[ h_{\text{ref}} = h_{p(t=0)} + h_{l(t=0)} \]

\[ h_{s(t)} = h_{p(t)} + h_{l(t)} - h_{\text{ref}} \]

hs scour depth
Velocity profiles and shear stress

Ub-flow: an acoustic profiler
Two transducers (1.5 and 3 MHz)

\[ u_x = 1,873 \times V_1 - 1,710 \times V_2 \]

\[ u_x(z) = \frac{u}{k} \ln(z) + B \]
\[ \tau_0 = \rho u^* \]
Abutment site

Data logger
Camera
Solar panels
Limnimeter
Raft with profiler
Results

- Instantaneous limnimeter data (m)
- Mean of 20 values (m)
- Banque Hydro water level (m)
- Rain (mm)
Results

Temporal evolution of the backscattered signal amplitude profile
Results

- March 6 at 20:43 water level stationary
- May 8 at 23:55, water level decreasing
Maintenance

Camera to keep an eye on biofouling
Conclusion & perspectives

- Monitoring real sites
  - could both help to prevent major failures and to have a better understanding of scour processes
  - should not only include bathymetric and water level measurements but also velocity profile
- Two innovative in situ monitoring devices have been presented
- Future research works will include
  - improvement of automatic data treatments,
  - detailed analysis of the data
  - Recommendations to managers
Thank you for your attention
LANAYE LOCK – PERTURBATION IN THE LOCK CHAMBER INDUCED BY ASSYMETRICAL FILLING

Author: Savary C., Bousmar D., Swartenbroekx C. and Zorzan G.

Service public de Wallonie – Hydraulic Research laboratory
Overview

• Introduction 4\textsuperscript{th} lock of Lanaye
• Commissioning tests
• Incident
• Optimization
• Observations on physical model
• Conclusion
Overview

• Introduction 4th lock of Lanaye
• Commissioning tests
• Incident
• Optimization
• Observations on physical model
• Conclusion
Introduction – 4th lock of Lanaye

Dimension: 225m x 25m
Head: 13.7m
Filling/Emptying system

Butterfly valves
diameter 3.5m
Overview

• Introduction 4th lock of Lanaye
• Commissioning tests
• Incident
• Optimization
• Observations on physical model
• Conclusion
Purpose of the measurements

• Check design criteria
  – Levelling time – maximum discharge
  – Mooring forces
    → Free-surface slope < 0.5 ‰
  – Lock generated waves in the reaches
• Quantify cavitation & vibration
• Optimization of valve opening schedule
• Check seals water tightness
Measurement set up

Water level measurements
• Absolute pressure gauges
• Precision < 5 mm
Measurement set up

Valve position
Measurement set up

Data acquisition devices

• Acquisition rate 20 Hz
• Synchronisation – cable loop
Symmetrical mode
Symmetrical filling – longitudinal slope

Linear regression – mean slope

water level (m DNG) vs. distance from the upstream door (m)

- right side
- left side

Service public de Wallonie | SPW Mobilité et Infrastructures
Symmetrical filling – longitudinal slope

![Graph showing average longitudinal slope over time.](image1)

![Graph showing max local slope over time.](image2)
Symmetrical filling – Transversal slope

RNA3 - Transversal slope

Time (min)

Transversal slope (%)
Asymmetrical mode
Asymmetrical filling – longitudinal slope

![Graph showing average longitudinal slope over time]

[Diagram of asymmetrical filling and longitudinal slope]

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Asymmetrical filling – transversal slope
Asymmetrical filling – transversal slope

![Graph showing transversal slope over time](image_url)

**RDA1 - Maximum transversal slope (absolute value)**

- **Max transv slope (abs) (%)**
- Time (min)

Service public de Wallonie | SPW Mobilité et Infrastructures
Asymmetrical emptying – transversal slope

VDA1 - Maximum transversal slope (abs)

Not an issue
Recommendations

→ Caution in case of asymmetrical filling
- Ships moored on the side of the operational culvert
- Caution if several ships in the lock
Overview

• Introduction 4th lock of Lanaye
• Commissioning tests
• Incident
• Optimization
• Observations on physical model
• Conclusion
Incident in Lanaye

Need to change the opening schedule of the valves for asymmetrical filling.
Overview

• Introduction 4th lock of Lanaye
• Commissioning tests
• Incident
• Optimization
  – Debriefing
  – Simplified approach
  – Site measurements
• Observations on physical model
• Conclusion
Debriefing video record / commissioning measurements

- **Begin of trouble**
  - Slope > 0.5/1000
  - ± 5 min on video

- **End of trouble**
  - ± 12 min on video
Debriefing video record / commissioning measurements

- **Begin of trouble**
  - Slope > 0.5/1000
  - ± 5 min on video
    Opening ≈ 50°

- **End of trouble**
  - ± 12 min on video
    After full opening
Debriefing video record / commissioning measurements

- Begin of trouble
  - Slope > 0.5/1000
  - ± 5 min on video
    Opening ≈ 50°
    Q ≈ 40m³/s
    z ≈

- End of trouble
  - ± 12 min on video
    After full opening
    Q ≈ 80m³/s
    z ≈

- Admissible filling discharge depend on the water depth
Overview

- Introduction 4\textsuperscript{th} lock of Lanaye
- Commissioning tests
- Incident
- Optimization
  - Debriefing
  - Simplified approach
  - Site measurements
- Observations on physical model
- Conclusion
Simplified approach

- 3D numerical model / physical model: no time / ressource
- Site measurements: OK for limited number of valve opening schedules
- → Simplified approach based on the link between the discharge and the water level in the lock chamber
Simplified approach

• ≠ opening schedules with steps
• Use of ALFREDO $\rightarrow Q(t)$ and $z(t) \rightarrow Q(z)$
• Chose max 3 opening schedules to test on site
Which opening schedule?
Simplified approach

- ≠ opening schedules with steps
- Use of simple numerical model ALFREDO $\rightarrow$ $Q(t)$ and $z(t) \rightarrow Q(z)$
- Chose max 3 opening schedules to test on site
ALFREDO

• Coupled model culvert / lock chamber
• Transient flow in the culvert
• 1D lock chamber
• Short Culvert / Longitudinal culvert
• Calibration of head loss coefficients on basis of in-situ measurements
Simplified approach

• ≠ opening schedules with steps
• Use of simple numerical model ALFREDO $\rightarrow Q(t)$ and $z(t) \rightarrow Q(z)$
• Chose max 3 opening schedules to test on site
Simplified method
Overview

• Introduction 4th lock of Lanaye
• Commissioning tests
• Incident
• Optimization
  – Debriefing
  – Simplified approach
  – Site measurements
• Observations on physical model
• Conclusion
In-situ measurements
In-situ measurements
Overview

• Introduction 4th lock of Lanaye
• Commissioning tests
• Incident
• Optimization
• Observations on physical model
• Conclusion
Position of the boat

El Ouamari & Lenaerts (2019)

Service public de Wallonie | SPW Mobilité et Infrastructures
Water slope = force?

El Ouamari & Lenaerts (2019)

Service public de Wallonie | SPW Mobilité et Infrastructures
Overview

• Introduction 4th lock of Lanaye
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• Incident
• Optimization
• Observations on physical model
• Conclusion
Conclusion

- Longitudinal culvert with side ports → problem with asymmetrical filling
- Adaptation of valve opening schedule
  - Transversal slope from 5‰ to 2 ‰
  - Filling time from 30 min to 45 min
- Complementary studies necessary for a better understanding

→ Recommendations
- Use specific opening schedule
- Use, if possible, the other parallel locks
- Ships moored on the side of the operational culvert
- Caution if several ships in the lock
Thank you for attention

Questions?

celine.savary@spw.wallonie.be
FEASIBILITY STUDY OF ITAIPU BINACIONAL LOCKS

Sébastien Roux – Centre d’Analyse Comportementale des Ouvrages Hydrauliques (CNR)

Wim Ridderinkhof – Witteveen+Bos International Projects

Daniel Alejandro Vázquez Bado - Centro Internacional de Hidroinformática/ Itaipu Binacional

Paul Ravenstijn – Witteveen+Bos International Projects
Itaipu Binacional
Itaipu Binacional

- Produces **15%** of the energy consumed in Brazil and **90%** of that consumed in Paraguay
- **120 m** water level difference between upstream and downstream
- daily average discharge up to **40,000 m³/s**
Feasibility Study for the construction of Bypass

- Feasibility study into the construction of a bypass along the dam. Consisted of:
  - Design of bypass (navigation channel and four locks)
- Fast-time nautical manoeuvring simulations
Why Fast-time nautical manoeuvring study?

- To determine if short (less expensive)

  This required detailed information regarding the flow field in the downstream Parana River for different discharges

2. Design ship: 2x2 barges pushed convoy of 160 m length and 16 m width
Methodology
Methodology

- Bathymetry in numerical model from:
  - multi-beam measurement (2018)
  - Topography and bathymetry before the construction of the Itaipu dam
- ADCP measurements were available for validation:
  - Extensive campaign on 15/02/2018: discharge between 12,500 and 14,000 m³/s
Results

- **Water level:**
  - Between 98.6 and 111.4 m + MCT for 90% of the time
  - Varied >35m in period 1983 – 2015

- **Discharge:**
  - Below 17,000 m³/s for 95% of the time
  - Downtime simulations upto 20,000 m³/s
Results: First results of numerical simulations

Significant discrepancies with the ADCP measurements of current fields that were obtained in the project area. Specifically:

1. Recirculation in front of the entrance to the bypass was not well captured by the numerical model
2. Systematic underestimation of the (average + surface) velocity in the river
Results: velocity field in Parana River

Add statement regarding importance of scheme for this study (Flow in river bend)
Results: velocity field in Parana River
Results: velocity field in Parana River

Transect P12

- Calcul
  - Conv14
  - dT1s
  - Inicial
  - KE_Visc1e-6
  - NH
  - Visc1e-4

Legend: Profiles ADCP 2018-02-15
- Profiles
- ADCP
- 0 250 500 1000 m
Fast-time simulations
• Assessment of the capacity for the design vessel to enter/exit the locks according to the flow condition, vessel manoeuvrability and towing power
Lessons Learned

- Few up to date data available for model calibration (bathymetry, velocity) Vs important issue depending on the results (go/no go for the next step of the project);
- Added-value of in-situ measurements;
- Synergy between IB / W+B/ CNR allowed to keep the FS on track even with a very tight schedule;
Conclusions

- Paraná River downstream of the Itaipu dam is highly variable and dynamic
- Typical water level fluctuations range over 12 m
- Typical discharges cause flow velocities over 2 m/s
- Explicit advection scheme was needed to be used to correctly model the return flow that occurs in the outer river bend.
- Fast-time nautical manoeuvring simulations: a design vessel can safely enter the designed bypass system
- 2x2 barges pushed convoy of 160 m length and 16 m width
- Discharges up to 20,000 m³/s
Thank you!
STUDY ON THE FILLING AND EMPTYING SYSTEM OF WANAN SECOND LOCK

Author: Wu Peng
Organisation: CCCC Water Transportation Consultants Co. Ltd
Overview of Wanan Dam

- Wanan Hydropower Station is located in the middle reaches of Ganjiang River, which is a tributary of the Yangtze River.
Overview of Wanan Dam

Main function
- generate electricity
- flood control
- navigation
- irrigation
- aquaculture

Storage capacity
- 2.2 billion m³

Operation
- in January 1996

- a single-step
- 175m × 14m × 2.5m
- two 500-ton barges
Overview of Wanan Dam

• Considering the development of vessels and the improvement of navigation conditions of the waterway in Ganjiang River, it is proposed to build the Second Lane of Wanan Lock.

• How to ensure the safety and efficiency of filling and emptying is the key technical problem to be solved in the construction of Wanan Second Lock.

The lift of Wanan second lock is 32.5m

- existing lock
  - 175m × 14m × 2.5m
  - two 500-ton barges

- new lock
  - 180m × 23m × 4.5m
  - 1000t class vessels
  - water conveyance is 164.45 thousand m³
Selection and layout of filling and emptying system

- "Design Code for Filling and Emptying System of Locks (JTJ306-2001)"

\[ m = \frac{T}{\sqrt{H}} \]

- \( T \) is the required time of filling the chamber (min)
- \( H \) is the design lift (m).

### Selection of filling and emptying system according to Chinese code

<table>
<thead>
<tr>
<th>( m )</th>
<th>Types</th>
<th>Specific patterns</th>
</tr>
</thead>
</table>
| \( >3.5 \) | concentrated filling and emptying system | - Short Culvert  
 - through the gate  
 - Combined system                                                  |
| \( 2.5 \sim 3.5 \) | concentrated or distributed filling and emptying system | - main culvert in the lock wall and side branch outlet                  |
| \( 1.8 \sim 2.4 \) | the second type of distributed filling and emptying system | - main culvert in the lock chamber and top branch hole  
 - main culvert in the lock chamber and side branch outlet  
 - Sectional outflow  
 - main culvert in the lock wall and transverse branch culvert |
| \( <1.8 \)  | the third type of distributed filling and emptying system | - balanced flow system                                              |
• **Wanan Lock**  \[ m = \frac{10-12}{\sqrt{32.5}} = 1.75-2.10 \]

• the gravity lock wall could be adopted for the structure of lock chamber according to geological conditions.

• a very complicated type of distributed filling and emptying system can be chosen.

**Selection and layout of filling and emptying system**

**Layout of filling and emptying system of Wanan Second Lock**
Selection and layout of filling and emptying system

- the sectional area of culvert in the valve section

\[ \omega = \frac{2C(\sqrt{H+d} - \sqrt{d})}{\mu T\sqrt{2g}\left[1-(1-\alpha)k_v\right]} \]

\( \omega \) is the sectional area of culvert in the valve section (m²)
\( C \) is the calculation water area of lock chamber (m²)
\( H \) is the design lift (m); \( d \) is the inertia head when the valve totally opened
\( \mu \) is the discharge coefficient of filling and emptying system when the valve entirely opened
\( T \) is the required time for filling the chamber (s)
\( \alpha \) is the coefficient to be selected according to the table in the code
\( k_v \) is a ratio of valve open time divided by filling time
\( g \) is the acceleration of gravity (m/s²).

- For the Wanan Second Lock:

\[ \omega = \frac{2 \times 5060 \times (\sqrt{32.5 + 0.5} - \sqrt{0.5})}{0.8 \times (600 \sim 720) \times \sqrt{2} \times 9.81 \left[1 - (1 - 0.43) \times 0.5\right]} = 36.4 \sim 30.3 \text{m}^2 \]

- the value of the sectional area of culvert in the valve section is decided to be 36.0 m².
Selection and layout of filling and emptying system

High lift (32.5) and the downstream water level varies (nearly 10m)

- The shallow burial of the valve and natural ventilation at the top of culvert could not be used to solve the cavitation problem.

The valve should be arranged at the lower elevation

- Relying on the greater pressure behind the valve to reduce the occurrence of cavitation behind the valve.

The burial depth of culvert of the valve section is 13m

The elevation of the culvert top should be 54.50 m

Filling valve (2~4m × 4.5m = 36m²)
Selection and layout of filling and emptying system

- The intake manifold is arranged on the front wall of the upper lock head.
- The total area of the intake manifold is determined with the criteria that the flow velocity should be less than 2.5 m/s.
- The submerged depth of the inlet should be more than 0.4 times the design lift according to the Chinese code.
Selection and layout of filling and emptying system

- The cross-section velocity is generally controlled within 10~12m/s.
- According to the estimated maximum flow of water filling, the culvert section needs to be more than 48.7~40.6 m². So the lock wall culvert section should be 2-4.0m × 6.0m=48.0 m²

upstream inlet  
2-6 × 4.0m × 6.0m=288m²

main culvert in the lock wall  
2-4.0m × 6.0m=48.0 m²

filling valve  
(2~4m × 4.5m=36m²)
Selection and layout of filling and emptying system

- The horizontal diaphragm of the vertical diversion is arranged in the lock chamber.
- In order to further control the cross-section velocity, the cross-section of the diversion is appropriately enlarged.
Selection and layout of filling and emptying system

- 0.48 m \times 1.0 m (6 holes)
- 0.44 m \times 1.0 m (6 holes)
- 0.40 m \times 1.0 m (6 holes)

Total area is 63.36 m²

- The culvert in the lock chamber is 4.0 \times 5.0 = 80.0 m²

- The total length of the outlet section is 2 \times 18 \times 4.0 = 144.0 m
The open ditch for energy dissipation is set outside the port to adjust and dissipate the flow into the chamber.
Hydraulic characteristics of the filling and emptying system

- Because of the high lift the cavitation of valve culvert section is one of the key technical problems to be solved in the design of filling and emptying system.
Hydraulic characteristics of the filling and emptying system

<table>
<thead>
<tr>
<th></th>
<th>the flat bottom culvert</th>
<th>the sudden expansion culvert</th>
</tr>
</thead>
<tbody>
<tr>
<td>flow coefficients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>filling</td>
<td>0.838</td>
<td>0.780</td>
</tr>
<tr>
<td>emptying</td>
<td>0.734</td>
<td>0.692</td>
</tr>
<tr>
<td>valve opening time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>filling</td>
<td>8 min</td>
<td>8 min</td>
</tr>
<tr>
<td>emptying</td>
<td>7 min</td>
<td>7 min</td>
</tr>
<tr>
<td>the maximum flow rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>filling</td>
<td>457 m³/s</td>
<td>403 m³/s</td>
</tr>
<tr>
<td>emptying</td>
<td>433 m³/s</td>
<td>402 m³/s</td>
</tr>
<tr>
<td>time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>filling</td>
<td>11.44 min</td>
<td>11.12 min</td>
</tr>
<tr>
<td>emptying</td>
<td>11.45 min</td>
<td>11.23 min</td>
</tr>
</tbody>
</table>

Comparison of model test results
Hydraulic model test of valve and selection of filling and emptying system

The flow pattern behind the culvert valve in the flat bottom section can be divided into 3 areas:

- a main flow area
- a main rotational flow area formed by the shrinkage and expansion of the flow at the bottom edge behind the valve
- a secondary rotational flow area at the upper boundary of the main flow

Diagrammatic sketch of the valve section culvert and flow pattern for the flat bottom culvert
Hydraulic model test of valve and selection of filling and emptying system

The flow pattern behind the culvert valve in the sudden expansion section can be divided into 4 areas:

- a main flow area
- a main rotation area formed by the shrinkage and expansion of the flow at the bottom edge after the valve
- a secondary rotation area at the upper boundary of the main flow
- a secondary rotation area caused by the falling jet.

Diagrammatic sketch of the valve section culvert and flow pattern for the sudden expansion culvert
Hydraulic model test of valve and selection of filling and emptying system

• The flat bottom culvert section is relatively simple and easy to construct. The sudden expansion culvert has shorter filling time and a lower maximum flow velocity. The flow pattern at the upstream inlet and approach channel also improved as the flow velocity in the valve section and main culvert decreased. In the sudden expansion culvert, the vertical space behind the valve is increased, and the main rotation area behind the valve is fully whirled.

• Compared with flat bottom culvert, although the top pressure of culvert decreases when the valve opening $n=0.1-0.3$, the natural ventilation of lintel is smoother, and the bottom cavitation can be sufficiently inhibited by the natural ventilation of lintel.

• When the valve opening is equal or greater than to 0.4, the main flow can diffuse rapidly along the way, which reduces the main flow speed and increases the pressure obviously.
Both two layout schemes of filling and emptying system (flat bottom type and sudden expansion type in culvert behind the valve) can meet the requirements of design and the code. The sudden expansion type has shorter water filling time and lower maximum flow rate.

In the sudden expansion culvert, the vertical space behind the valve is increased in the top and at the bottom of culvert, and the main rotation area behind the valve is fully whirled. Combining with natural ventilation measures of lintel, the problem of valve cavitation of Wanan second lock can be solved.

The distribution of ports with different areas and open ditches outside the ports has achieved the anticipated results in improving the mooring conditions of vessels in the lock chamber. The flow in the chamber is relatively stable under different operation conditions, and the vessel has no drift during the rising process, and the flow at diversion structure is balanced.
Study on the Filling and Emptying System of Wanan Second Lock

Thank you for listening

Construction began on December 28, 2018