Standardization of steel suspended gates with lateral movement for 4 new locks in the Walloon Region (Belgium, Canal du Centre and Canal Charleroi-Bruxelles)

David Monfort, Romain Marcelle, Viviane Warnotte, Benjamin Jodogne

Engineering office Greisch, Liège, Belgium

Contact: dmonfort@greisch.com

Abstract

During the standardized study of 4 new locks to build on the Canal du Centre and the Canal Charleroi-Brussels (Navigation class Va, Belgium), the choice was made for suspended gates with lateral movement. In this context, the design of the gantries allowed for a series of innovations, compared with conventional practices. This results in a simple, intuitive structure, which optimizes the total weight of the steel structure (gantry + gate) and makes the closing movements of the chambers safer.

About the gate panels themselves, special attention was paid to limiting crusting of the immersed structure. This results mainly in vertical stiffening, with no intermediate horizontal crossbeams.

Standardization between the 4 sites is guaranteed for all the steelwork components, notably through different levels of fender fastening and technical footway adjustment possibilities. A spare gate is provided with additional standardization features.

Keywords: Lock gate, steel gantry, cable suspension, standardization, weight optimization, maintenance.

1 Introduction

For a project author, the design of engineering structures and moving parts provides an opportunity to question uses and develop new technical solutions.

In the present design, these are guided by simplicity of form, optimisation of materials, operational safety and standardisation between sites.

During the study of 4 new locks to build on the Canal du Centre and the Canal Charleroi-Brussels (Navigation class Va, Belgium), special attention was paid to the study of the gates with lateral movement as well as the design of their suspension gantries.

Several accident risks are considered in the calculation and design.

Consequently, technical accesses are also integrated into the various structural elements.

The article reviews the main innovations and optimisations developed in this study.

Figure 1. General integration of the work into the site

Figure 2. Overview of the Gosselies site

2 Definition

A navigation lock consists of a chamber with appropriate dimensions (according to the size of the vessels) which makes a barrier between upper and down water levels. It is ended both ways by movable gates: these allow for a watertight closure of the chamber, either separately (during movements of the ships) either together (during filling or emptying operations).

The gates with lateral movement are flat structures, suspended from a transversal gantry, and manoeuvred by means of a motorised trolley travelling on an upper roller track.

In closed position (= navigation interrupted and lock chamber filling or emptying), they cover the entire width of the lock (here 12.5 m) and, due to the hydrostatic pressure, are supported on 3 of their sides (the 2 vertical sides and the bottom concrete sill).

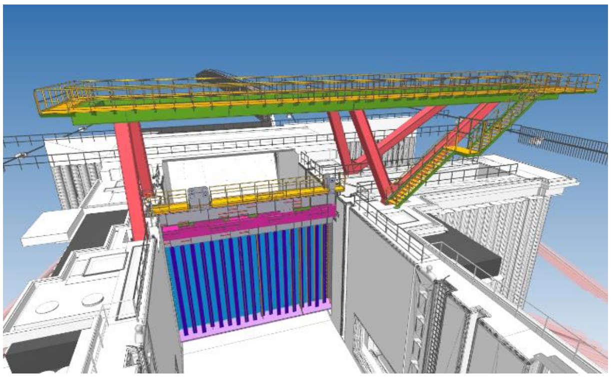

Figure 3. Supports of the gates with lateral movement

In the open position (= navigation in progress, water levels equalised), they are offset outside the river gauge and hang freely in a lateral recess for sluice gates.

3 Reference design

In their usual use, these structures are suspended by a single long cable, running through a set of upper and lower pulleys. Historically, this arrangement was meant to raise the door for exceptional maintenance without the need for additional handling equipment. This required to roll up the single cable up to the desired vertical position of the hanging gate. In practice, this option is rarely used, or even impossible depending on the cable wear.

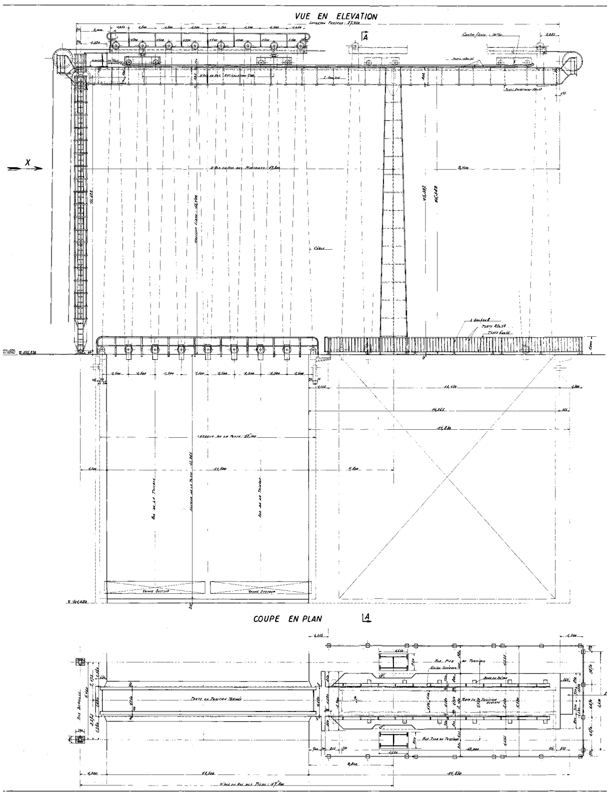

Figure 4. Existing gantry at the Gosselies site

Figure 5. Existing gantry at the Viesville site

Such a design requires the creation of a continuous upper trolley, capable of supporting the per unit length weight of the gate panel. At the beginning and end of the manoeuvre, the swinging of the gate is slowed down by the mechanical friction of the cables and the hydraulic brake of the submerged panel.

The longitudinal stability of the gantry is generally ensured by an independent wind bracing. Access for maintenance requires an additional staircase.

These various aspects are discussed below.

4 General data

The main dimensions and weights of the steel parts are summarised in the following table:

Table 1. Gate height (m)

	Marchienne, Gosselies, Viesville	Obourg
Upstream	6.5	6.5
Downstream	12.75	10.9

Table 2. Gate weight (tons)

	Marchienne, Gosselies, Viesville	Obourg	Spare gate
Upstream	60	60	60
Downstream	95	90	-
Combined	-	-	106

The suspension gantry is identical for all locks and gates: it weighs 150 tons.

5 Optimizations

5.1 Creation of a gantry with inclined legs, guaranteeing horizontal stability without additional bracing

The gantry must be able to withstand the vertical loads of the gate and the longitudinal actions when it is set in motion and braked. It also absorbs transverse effects (especially wind).

In terms of navigation clearance and the different positions that the gate must occupy, the design with angled legs was found to be the most effective, making it possible to limit the number of bearing points while creating a natural axial bracing.

The different loading and cantilever configurations have been considered in the calculation.

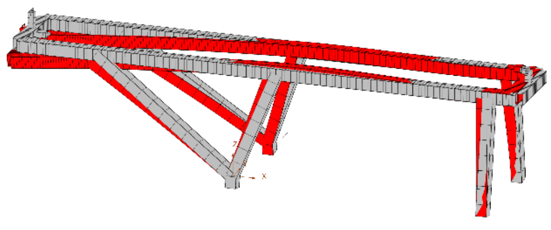

Figure 6. Digital modelling of the gantry (FinelG, Greisch)

5.2 Isostatic suspension by 2x3 independent cables, with the same inclinations as the gantry legs

In line with this design, the gate suspension has been transformed into a set of 3 cables (lengths of 6 m, 11 m and 6.5 m), positioned at the same inclinations as the legs of the gantry. The path of the forces is therefore a replica of the previous one, this time from the bottom up. In addition to the resulting visual elegance, this choice allows the panel to be held axially by the cables, which this time are independent of each other, and therefore able to transmit a braking or acceleration force to the manoeuvring trolley.

This point is very important in terms of operational safety. Indeed, once the door has closed, the operator naturally aims to vary the water level in the chamber as quickly as possible. However, the residual swing that occurred with existing suspensions (single cable running through a series of pulleys) can lead to inadequate support and potential risks of instability of the gate when the hydrostatic load on it gradually increases (i.e. when emptying in the case of the upstream gate and when filling in the case of the downstream gate). This type of incident is avoided by the suspension developed in this project. The movements of the trolley and the gate are much better synchronised: only the elastic elongation of the cables can still generate a very slight shift in translation. The sideways opening of the gates can take advantage of this stiffness to limit the duration of the manoeuvre.

The independence of the suspension cables also provides redundancy to the system, for which cases of accidental breakage have been considered, with their impacts on the other cables (here: deformed position in red with 5 cables out of 6).

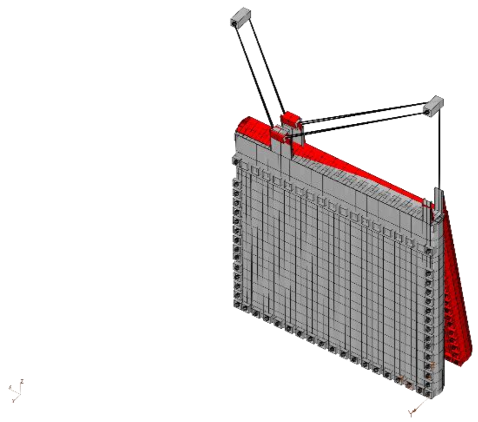

Figure 7. Modelling of the suspension, with accidental cable breakage (FinelG, Greisch)

5.3 Mobilization of the door panel's stiffness to lighten the suspension cart running on the top track

An additional effect of this provision is the improved use of the gate panel as a self-supporting element: it is very strong in its own plan and can be suspended at two points. This allows the support reactions to be directed towards localised and therefore lighter manoeuvring trolleys.

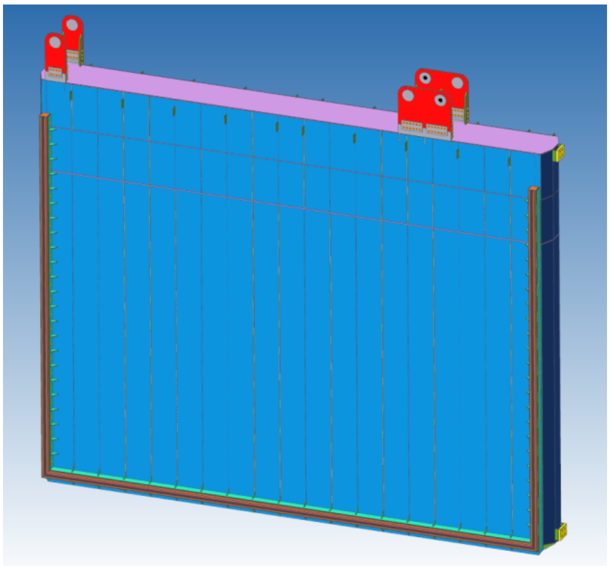

Figure 8. Location of suspension points

5.4 Simplicity of gate panel

To limit the encrustation of the leaves, a unique stiffening design has been developed: relying on the inherent rigidity of the metal panel in its plan, only vertical needles have been placed. These run from bottom to top, between the lower crossbeam and the upper box. The latter acts as a support for the fenders (in the event of a collision with a boat) and also houses the technical footbridge.

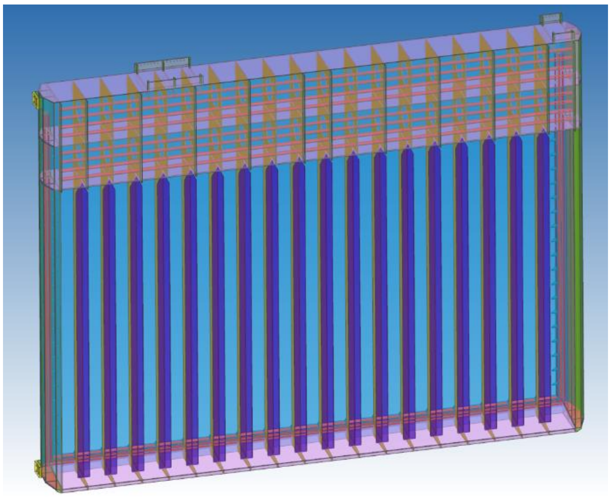

Figure 9. Panel stiffening principle

This arrangement of stiffeners with reduced crusting risks is of high importance in the prospect of daily operation (control of the gate weight) and maintenance (simplicity of repair and painting operations).

5.5 Standardization

The navigation gauge is the same for all four locks, with an opening of 12.5 m, a water depth of 4 m and a clearance height of 7 m. Three of the four sites have similar drops (between 6.7 m and 7.4 m). The fourth lock has a lower drop (around 5.5 m).

The 4x2 gantries are strictly identical.

In order to guarantee their interchangeability, the lock gates are identical, with slight adaptations (modularity).

5.5.1 Fenders

One main design aspect of a lock gate is the ship collision. While entering the chamber or slowing down at the end of it, the vessels might touch the gate, with a variable speed. Accidental loads must therefore be considered, especially on the top beam of the structure.

The kinetic energy of the boat (and an added water mass) must be absorbed by a combination of elastoplastic springs. These consist of a line of rubber fenders and the flexibility of the gate panel itself. The anchor points of the shock absorbers are designed to cover the range of drops encountered in the three highest locks:

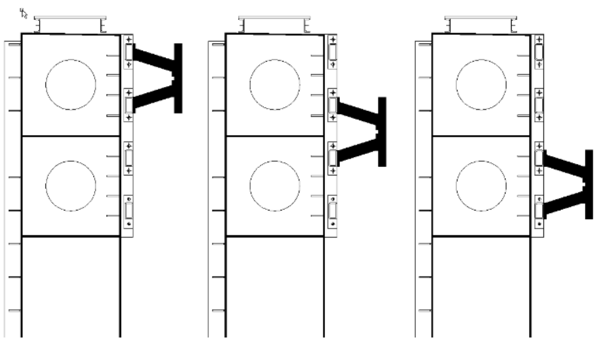

Figure 10. Different positions of the protective fenders, depending on the lock concerned

5.5.2 Lifting lugs

The height of the lifting lugs varies from one lock site to another. Actually, these are the adjustable pieces that allow the gate panels (under) as well as the suspension system (above) to be exactly identical.

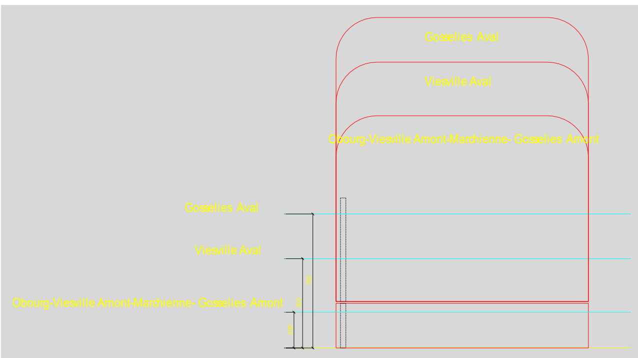

Figure 11. Different heights of the lugs

5.5.3 Technical footbridge

The footbridge connects both sidewalls of the lock and is dedicated to survey and maintenance operations of the gate. Its level matches perfectly the one of the platforms at each end.

In the standardisation process, the structure of the footbridge (in yellow hereunder) is linked to the gate's lifting lugs, so that it adapts to the drop encountered.

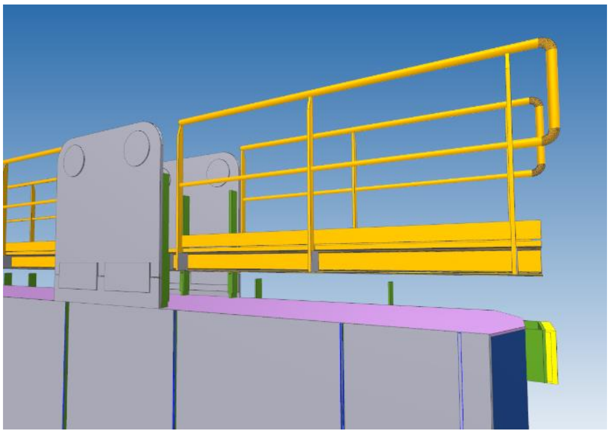

Figure 12. Overhanging of the footbridge on the lifting lug

5.5.4 Spare gate

3 stackable structures ensure the versatility of the spare gate:

- For the 3 highest locks, all the blocks will be assembled (from the bottom to the top): block 1 (7 m) + block 2 (1.85 m) + block 3 (3.9 m).
- For the fourth lock, with a lower drop, only the lower panel and the upper box will be assembled (block 1 + block 3).

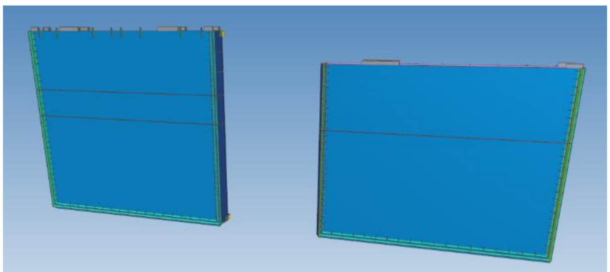

Figure 13. Assembled view of the spare gate

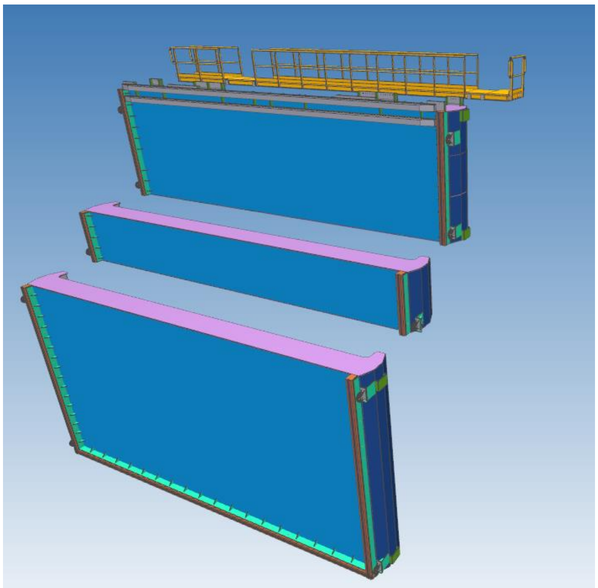

Figure 14. Exploded view of the spare gate

It should be noted that the upper box is completely identical on all sites, as it houses various equipments such as fenders and footbridges. This unique set of spare pieces covers thus all the situation encountered over the 4 sites.

However, on a structural point of view, the bolted connections in the middle of the panels lead to fatigue details that slightly reduce the expected lifetime of the steel structure (compared to a single leaf). As a spare element though, it has been considered sufficient, regarding all advantages offered by the modularity of the gate.

5.6 Beams for heavy maintenance situations

Usual maintenance of the gate can be made quite simply ('on site'). The lateral recess hosting the gate in its open position is closed by temporary watertight panels which allow for drying out the area. Inspection and local repair operations are executed in this configuration.

A heavier repair (for instance after a significant ship collision) requires the gate panel to be lifted above the water level. Specific beams have been developed for such operations:

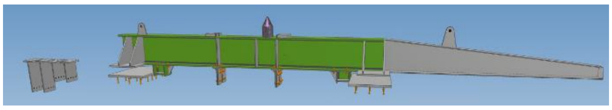

Figure 15. Supporting beams for heavy repair

- Two of these are first placed across the recess, in a transversal position.
- The gate is connected to these beams, thanks to adjustable lugs (according to each site)
- A jacking operation transfers the load of the gate from the cables to the beams.
- The cables are removed, and the upper trolley is pushed further on the rolling path.
- An external crane carries the gate and liberates the beams (these are temporarily removed)
- The gate is raised up to its repair position and placed back on the beams: these are equipped with centring cones, as shown on the picture below.

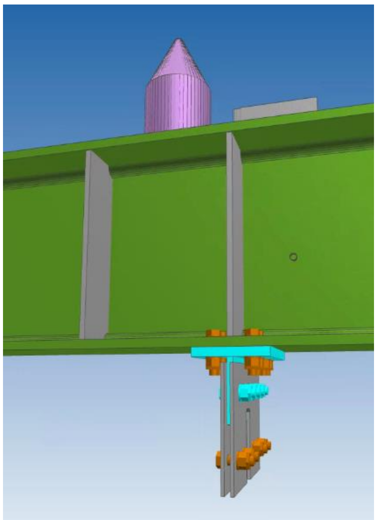

Figure 16. Detail of the lifting plates and the upper cone

5.7 Integration of a maintenance access along one of the gantry's legs

Technical access is required for regular inspection and maintenance of the manoeuvring trolleys running on the upper rails of the gantries.

Taking advantage of the presence of legs, we place the cantilevered staircase on one of these, by means of a swing over 2 consecutive spans. This simple design avoids the addition of a complementary structure and offers a direct and axial path.

6 Conclusions

The combined design of the new gantries, gates and equipment provides a customised, standardised and optimised solution for operating the four locks.

Elements such as safety in use, reduction and simplification of maintenance, the legibility of the structure and its integration into the landscape are all strong points of this solution.

Figure 17. Overview of the Marchienne site