

New ship lift at Niederfinow – the planning process and technical aspects

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Summary

A second ship lift is to be constructed in Niederfinow adjacent to the existing lift. After extensive preliminary studies, the Federal Waterways Administration decided on a vertical lift with balancing counterweights. A load-bearing structure consisting of reinforced concrete towers, columns and cable pulley girders, all with foundations in a common caisson well, transfers the loads from the water-filled caisson (9 000 t) into the bedrock via cable pulley girders. The caisson, which is suspended on cables and balanced with counterweights, has a usable length of 115 m, a usable width of 12.5 m and allows a water depth of 4.0 m. Vertical movements of the caisson take place by means of rack and pinion drives. A safety system consisting of internally threaded columns and rotary locking bars ensures that the caisson stops safely in an emergency. Official permission for construction was granted on 04.01.2005 and the execution design of the lift was approved on 03.01.2006.

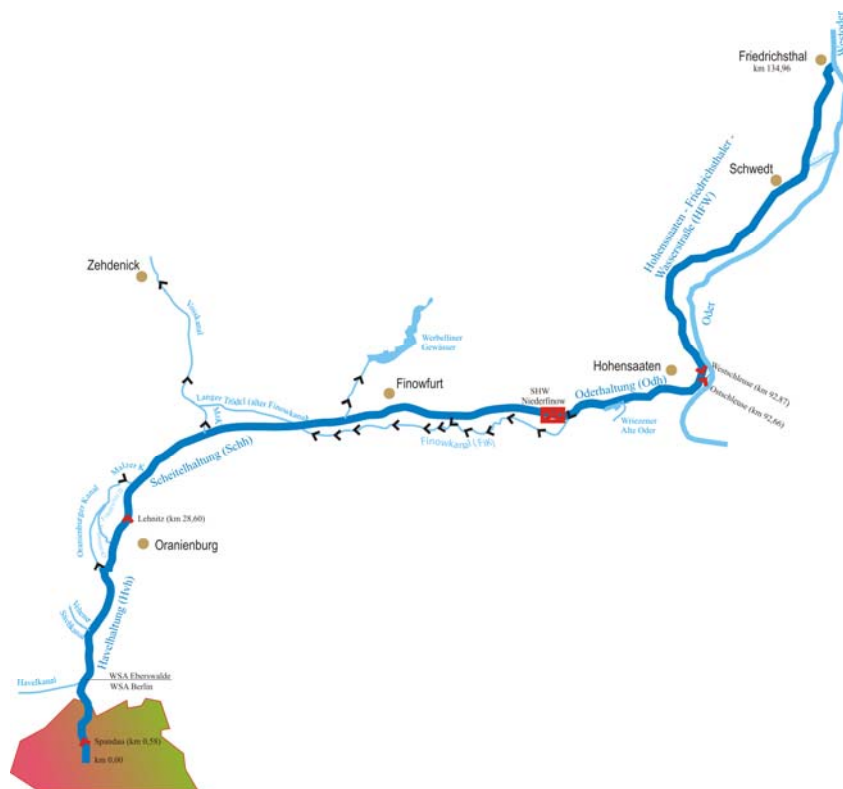


Figure 1. Overview

On 16.05.2008, the contract to construct the new ship lift was awarded to the Neues Schiffsbauwerk Niederfinow consortium, consisting of Bilfinger Berger Ingenieurbau GmbH, DSD Brückenbau GmbH, Johann Bunte Bauunternehmung GmbH & Co. KG and Siemag M-Tec² GmbH. The consortium started work in summer 2008.

The ship lift is expected to go into operation in 2014.

1. Historical background

The completion of the Finow Canal in 1746 created a waterway that linked Berlin with the Baltic port of Stettin and had a decisive influence on the economic revival and effect of trade in this region. Transportation of goods by water increased so much over time that at the beginning of the last century, demands for a significantly more efficient waterway became louder and louder. As a result, the Oder-Havel Canal was built in the period from 1907 to 1914 as a replacement for the Finow Canal. 14 locks on the Finow Canal were replaced by a flight of 4 locks in Niederfinow, each with a rise of 9.0 m.

The long waiting periods at the lock system and initial structural problems with the locks led to pressure to construct a second descent in Niederfinow, which had been planned as early as 1905. Following intensive planning and six years of construction, the Niederfinow ship lift went into operation in 1934. In subsequent years, it became much more popular than the flight of locks due to its much shorter transition times. Its declining attractiveness for shipping and an increasing number of structural defects led to decommissioning of the flight of locks in 1972. The remains of the structure are now a historic monument.

Due to its sound construction, the lift that opened in 1934 has only been out of service for 60 unplanned days in 72 years of operation. Guaranteeing such a high level of operational readiness has, however, led to high maintenance costs and increasingly extensive repair work.

The dimensions of the present caisson (85.0 m x 12.0 m x 2.5 m) represent a significant limitation to shipping with today's vessels. Moreover, cost-effective container traffic cannot be developed because of the maximum permissible passage height of 4.0 m. These considerations led the Federal Ministry of Transport to instruct the waterways construction office in Berlin (WNA Berlin) to plan and construct a new descent on the Havel-Oder waterway (HOW) in Niederfinow in the context of urgent requirements for new construction and improvement measures on federal waterways.

2. New ship lift

2.1 Preliminary studies and basic principles

As a first step, a preliminary study clarified basic questions regarding the site, the technical concept and the dimensions of the new structure.

Four alternatives for the route of the new descent were to be studied and ranked in order of preference, the most important criteria being conditions for shipping, cost-effectiveness and environmental compatibility. In a second step, the descent structure itself was selected and defined. Aspects such as traffic forecasts, fleet structure, operating concepts, operational safety, construction costs, operating and maintenance costs were to be taken into consideration. Different types of structure were considered, such as a shaft lock, a flight of locks, a water slope, an inclined plane, a lengthwise inclined lift and a vertical lift. A decision also had to be made on whether there should be one or two new descent structures in the future.

As a result of all these studies, a new vertical lift positioned between the existing lift and the decommissioned flight of locks was determined to be the best solution. The caisson was to be dimensioned for ships up to 114.0 m long, 11.60 m wide and with a draught of up to 2.80 m.

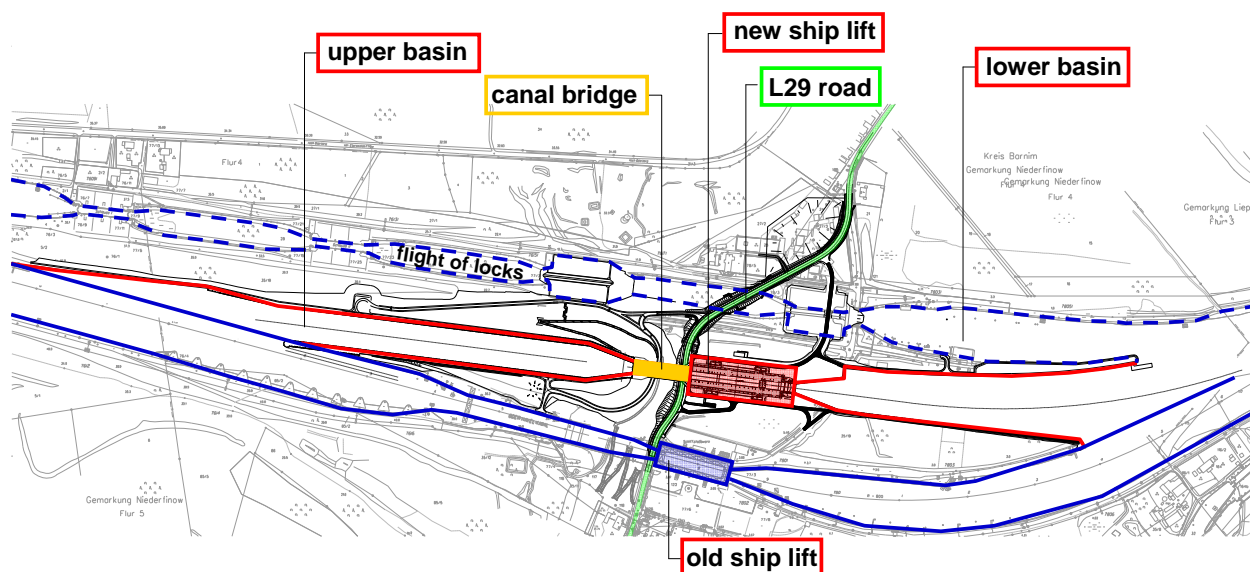


Figure 2. Overall plan

After a presentation of the results of the preliminary study, the Federal Ministry of Transport approved the proposed solution, thus giving the go-ahead for further technical processing and planning of the new ship lift.

The first stage of planning was to establish the technical details of the structure. Ship lifts in Niederfinow and Scharnebeck (Germany) and in Strépy Thieu (Belgium, still under construction at that time) served as models.

Experience of operations and maintenance and the technical advances made since the planning of these lifts led to a large number of detailed questions which were collected to form an extensive questionnaire. The answers to these questions provided by a special project group and their confirmation by a decision-making body led to the design principles on which the further planning process was based. Particular attention was paid to the dependencies between the load-bearing structure, the caisson suspension, the drive system and the locking system.

As a result of all this preparatory work, the following concept was developed:

- the load-bearing structure extends over the entire length of the caisson
- the load-bearing elements subject to compression are made of concrete, those subject to bending forces are made of steel
- the cables that connect the caisson with the counterweights are attached directly to the caisson
- in the same way as in the existing lift, the caisson is secured by a rotary locking bar/internal thread column system.

2.2 Foundation soil

Niederfinow is at a latitude of around 53° north, so the last three Ice Ages have shaped the site of the lift. In each of the Ice Ages, the mighty glaciers twice moved southward past Niederfinow. On each occasion, they changed the foundation soil, eroding the soil and deforming the bedrock and as they retreated, they deposited sediments that formed new layers of soil. To be able to give accurate information about conditions below the surface, the Federal Waterways Engineering and Research Institute (BfG) developed a digital 3D-model of the subsoil based on drill logs. For this model, in addition to new information, they also evaluated drilling data from the construction of the existing lift and the flight of locks. A total of 371 drill logs and 150 cone penetration tests from several drilling campaigns were used. The deepest boreholes were 120 m deep.

This information enabled the waterways construction office (BAW) to produce a foundation soil report on which the technical planning could be based. This report was updated during further processing to reflect the interactions between the foundation soil and the structure.

2.3 Planning approval

Once the construction budget had been approved by the Federal Ministry of Transport, it was necessary to follow the procedure for obtaining planning approval for construction of the lift in accordance with the Federal Waterways Act. The scope of the project and its effects on public and private interests had to be represented in the necessary application documents. These effects include the project's impact on the environment, landscape, traffic, local residents, planning of nearby communities and water management. The Federal Institute for Hydrology presented the effects of the project on nature and landscape in a study of environmental compatibility. An accompanying plan for landscape conservation explained the Federal Waterways Administration (WSV) vision of how negative effects could be countered.

After the application for planning approval was submitted in 2001 by the waterways construction office in Berlin, the documentation was processed and evaluated in 2002 and 2003. Planning approval was granted by the authorities in 2005.

3. Technical solution

3.1 General description

The new ship lift facility is located at the foot of a 36 m high escarpment and consists of:

- the ship lift with its load-bearing structure, caisson with counterweights, caisson safety system, caisson well and lower docking station
- the canal bridge with abutment, safety gate and upper docking station
- the upper basin that branches off the summit reach of the Havel-Oder waterway and the lower basin that opens out into the Oderhaltung area of the Havel-Oder waterway.

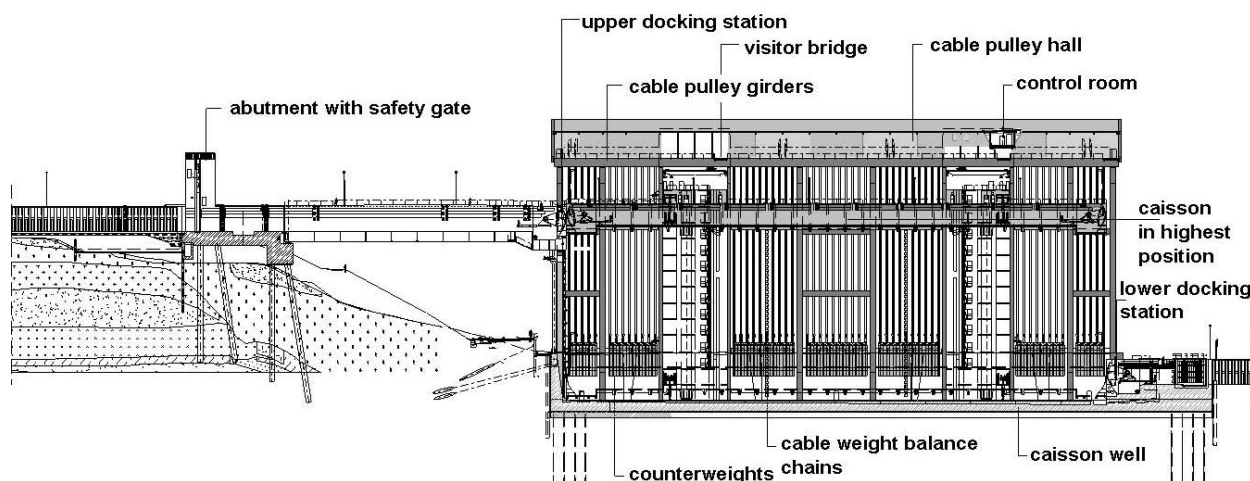


Figure 3. Longitudinal section

Table 1. Main dimensions:

	Height	Width		Length
Ship lift	55.0 m	32.4 m	46.7 m ²⁾	154.0 m
Caisson	7.5 m	18.3 m	27.5 m ²⁾	125.5 m
Caisson well (exterior)	11.0 m ¹⁾	36.5 m	48.2 m ²⁾	133.2 m
Canal bridge	8.2 m	21.7 m	28.4 m ³⁾	65.5 m
Upper basin		46.5 m		990.0 m ⁴⁾
Lower basin		46.5 – 90.0 m ⁵⁾		800.0 m ⁴⁾

- 1) depth to upper surface of caisson well sole
- 2) in the area of the pylons/drive housings
- 3) western support, without side extension for visitor walkways
- 4) length of waiting area for commercial shipping
- 5) widening due to curve

3.2. Basic design principles and load assumptions

Before the start of the planning process, basic design principles were established from which all load assumptions and other basic planning information could be derived.

The most important design principles are:

3.2.1. Water levels

Water levels in the upper pound (summit reach of HOW)

$$BWo + \text{dyn } z = \text{NN } +37.60 \text{ m}$$

$$BWo = \text{NN } +37.55 \text{ m}$$

$$\text{Top water level} = \text{NN } +37.25 \text{ m}$$

$$BWu = \text{NN } +37.05 \text{ m}$$

$$BWu - \text{dyn } z = \text{NN } +36.95 \text{ m}$$

Water levels in the lower pound (HOW, Oderhaltung)

$$BWo + \text{dyn } z = NN + 1.85 \text{ m}$$

$$BWo = NN + 1.85 \text{ m}$$

$$BWu = NN + 1.20 \text{ m}$$

$$BWu - \text{dyn } z = NN + 1.20 \text{ m}$$

3.2.2. Period of operation

The ship lift is to be in operation for 80 years with 310 days of operation per year, 16 hours per day and 0.5 hours transition time.

3.2.3 Design principles

Typical values of the forces

The values specified in DIN 19704-1, Point 5 apply with the following additions:

- hydrostatic design water level taking wind and surge into account
= $BWo + \text{dyn } z$
- hydrodynamic effect on ship movement = $\pm 0.11 \text{ m}$ (in addition to hydrostatic design water level)
- area load due to ice pressure (side walls) = 150 kN/m^2 (at height BWo),
thickness of ice = 0.30 m
- area load = 150 kN/m^2 (at height BWo)
- ice thickness = 0.30 m
- raising of the bearings

raising of one bearing axis with hydraulically coupled presses under its own weight plus a water layer 0.20 m deep

- wind load
According to the expert report on wind, the effect of dynamic pressure of $qK = 0.4 \text{ N/m}^2$ transversely and $qK = 1.3 \text{ kN/m}^2$ longitudinally to the bridge with an aerodynamic force coefficient of 2.1 is to be taken into account.
Height of traffic area 4 m above BWo

- sunken ship

in the water-filled canal bridge (water level at BWo)

load on floor of canal bridge $p_s = 26 \text{ kN/m}^2$

load width $B_2 = 11.4 \text{ m}$

load length $L_s = 110 \text{ m}$

in a transverse direction in the most unfavorable position for the building component involved

in the empty canal bridge

load on floor of canal bridge $p_s = 30 \text{ kN/m}^2$

otherwise as above

3.2.4. Combinations of loads

Based on the requirements of DIN 19704-1, basic combinations and extraordinary combinations were considered with the loads and factors given in Table 2 below.

Table 2

Partial safety factors γ_F and combination factors ψ for ultimate limit state checks (not including proof of fatigue strength) for the steel construction of the canal bridge								
No.	Type	Forces	Basic combinations			Extraordinary combinations		
			Case 1	Case 2	Case 3	Case 4 ²⁾	Case 5 ²⁾	Case 6 ²⁾
1	constant	Self weight	$\psi = 1.0$			$\psi = 1.0$		
2	variable	Hydrostatic design water level	$\psi = 1.0$	$\psi = 0.9$	$\psi = 0.9$	$\psi = 0.8$		
3		Hydrodynamic force from ship motion						
4		Live load						
5		Accelerating + braking forces						
6		Change to support conditions						$\psi = 0.8$
7		Raising of bearings						
8		Ice pressure						
9		Temperature ³⁾						
10		Wind			$\psi = 0.8$	$\psi = 0.8$	$\psi = 0.8$	
11		Friction from ships			$\psi = 0.9$			
12		Resistance to motion and deformation in the bearings, movable joints and seals		$\psi = 0.9$				
13	extraordinary	Impact of ship ¹⁾				$\psi = 0.8$		
14		Sunken ship, canal bridge full				$\psi = 0.8$		
15		Sunken ship, canal bridge empty					$\psi = 0.8$	
16		Snow during construction						$\psi = 0.8$
17		Special loads during construction						$\psi = 0.8$

¹⁾ DIN 19704-1 Point 7.2 applies to the ship arrester equipment

²⁾ Superposition of constant and variable forces with one extraordinary force in each case

³⁾ When using the temperature fields for the exceptional combinations, the partial safety factor $\gamma_F = 1.15$ can be used

4. Ship lift

Like the existing lift, the ship lift is a vertical lift with a water-filled caisson, the mass of which is balanced by counterweights. The water-filled caisson weighs around 9000 t. It is suspended from 224 cables with 220 counterweights and 4 counterweight balance chains over cable pulleys on the cable pulley girders. Balancing the caisson with the counterweights reduces the drive force required, which only has to overcome friction, start-up resistance, inertia and small differences in water level. The load from the caisson and counterweights is transferred into the foundation soil via a load-bearing structure that is symmetrical about its longitudinal axis.

The usable length of the caisson is set at 115 m, and the usable width of the opening for shipping at 12.5 m. There are no structurally active parts of the load-bearing system above the caisson, which means that the passage height can be increased at a later date with adjustments to the visitor bridges and the control room as necessary.

The maximum operational water level on the summit reach lies at sea level + 37.55 m and the minimum low water level in the Hohensaaten pound is at sea level + 0.98 m. The maximum distance travelled by the caisson between the docking stations is therefore 38 m.

In every position, the caisson safety system protects the caisson against unintended movements should the planned imbalance between the caisson and the counterweights be exceeded (e.g. due to excessive water loss); when it comes into play, the caisson drives are shut down electrically.

In the docking positions, the caisson is held in position by a caisson locking mechanism and the clearance between the caisson and the pound is closed by the clearance sealing system. The clearance is filled from the adjacent pound and the gates are opened so that the lift is open for ships to move in or out.

After the gates have closed, the water level in the caisson is adjusted to the correct level (if necessary) using reversing equipment. The clearance is emptied, the clearance sealing system is opened and the caisson locking mechanism is released. The caisson is then free to travel to the opposite docking station.

The caisson drives are constructed in such a way that all components are easily accessible, in order to minimize maintenance and repair costs.

The lift is operated from the control room which is located above the caisson between the eastern pylons.

4.1 Load-bearing structure

The load-bearing structure transfers the loads of the caisson and counterweights via the cable pulleys into the cable pulley girders and from there via two pylons and six cable pulley girder piers on each side into the bedrock via the caisson well.

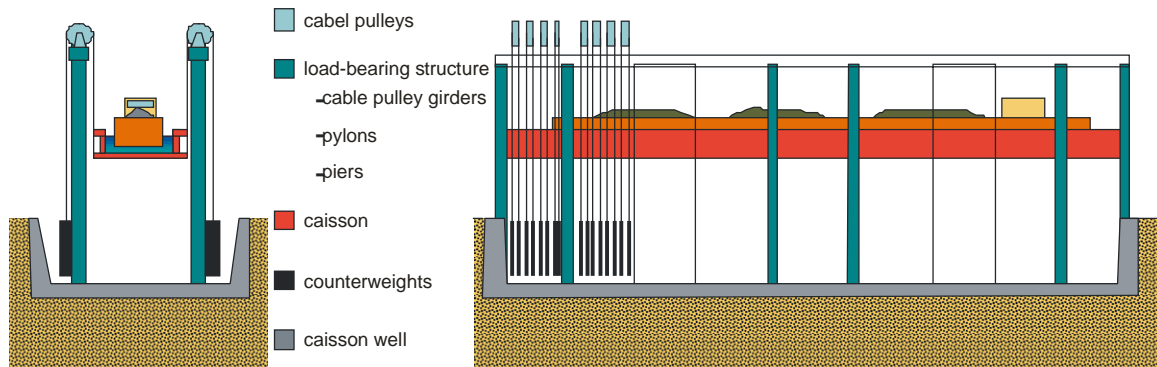


Figure 4. Principle of the load-bearing structure

The caisson well is a half-frame which lies flat on the underwater concrete base of the construction pit. The sides of the load-bearing structure are not connected in a statically effective way. The cable pulley girders, cable pulley girder piers, pylons and caisson well are rigidly connected. Viewed as a total system, they form a half-frame with substantially separated sides of variable stiffness. In the east, the caisson well merges into the lower pound.

The load-bearing structure supports the eastern support of the canal bridge, the cable pulley hall, the control room, the visitor bridges between the canal bridge and the western pylons, the visitor bridges between the pylons and also the lattice girders between the pylons. To support the canal bridge, the westernmost cable pulley girder piers are connected with each other by a concrete tie bar.

Steel of quality S355 was specified for the cable pulley girders which are subject to bending loads and for the caisson. For the pylons and piers, which are primarily subject to compression, and also for the caisson well, which is integrated into the site foundations, concrete of quality C35/45 was chosen. In order to achieve an attractive concrete surface, sample formwork drawings patterns were produced which specify the formwork material including its distribution and construction joints.

4.1.1 Cable pulley girders

The two cable pulley girders run lengthwise along the lift above the pylons and cable pulley girder piers. They support the loads from the cable pulleys, cable pulley hall, visitor walkways, visitor bridges and control room.

Their overall length is 131.2 m, their height is 2.0 m and their width 7.2 m. They are manufactured as hollow sections from plates up to 40 mm thick. On each cable pulley girder the twin cable pulleys are supported in bearing blocks, except in the areas above the pylons. The 256 counterweight cables running over the cable pulleys are guided through the cable pulley girder through openings of $d = 520$ mm.

4.1.2 Cable pulley halls

Two cable pulley halls protect the cable pulleys from the weather. They are 131.2 m long, up to 9 m high and around 8 m wide at their base. Including a canopy cantilevered inward over the visitor walkways, their roof width is 10.60 m.

Lengthwise, each cable pulley hall is divided into five sections. The cable pulleys are located in the outer and center sections. In the sections above the pylons, the visitor routes and emergency routes cross over to the stairwells and elevators located in the pylons on the outside of the buildings. The section above the eastern pylons has a further storey through which the control room is accessed and in which operations rooms are located.

The external shape of the cable pulley halls is a feature of the architectural design; they have pent roofs which incline inwards at 14°, outer walls that incline outwards by 3°, roof covering and façade cladding with profiled aluminum panels and glazing of the end surfaces and internal walls.

To allow replacement of the cable pulleys, the roof beams and covering can be completely removed.

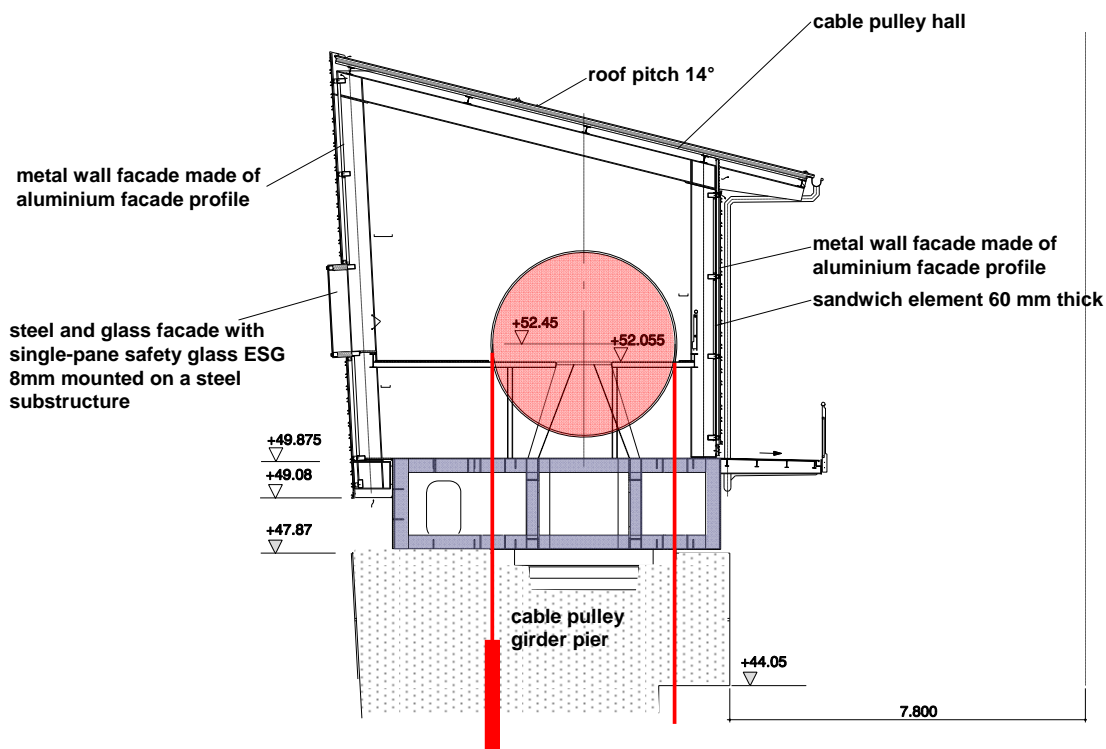


Figure 5. Cross-section of a cable pulley hall

4.1.3 Pylons

The pylons are 52.30 m high above ground level, 16.50 m long, 14.45 m wide and they extend up to 11 m below ground level. They stand on the caisson well at 6.40 m below sea level so that in the lower area, their outer walls form part of the caisson well. 17 planes divide the pylons horizontally, 14 of which lie above ground level. In general the stories are 3.73 m high.

The length of each pylon is determined by the caisson drive room which moves inside the pylon; its width is determined by the dimensions of the crane on the 15th floor and those of the stairwells, passageways and caisson drive room.

The floor plan of the lower 13 stories is divided into three parts. Towards the caisson, a 5 m wide U-shaped area for the caisson drive rooms opens. At its rear, the internally threaded columns and the rack ladder are anchored securely to the pylons. The stairwells, the supply shafts for power and water and the elevators are located on the outside. In the center there is an installation shaft and a passageway zone which separates the caisson area and the stairwells from each other for fire protection purposes.

The floor plan of the upper 4 stories is divided into two parts. On the outside, the stairwells, supply shafts and elevators continue upwards. On the inside, the 14th and 15th stories contain the area in which the crane moves, the 16th storey contains a passageway for visitors, and the 17th storey of the eastern pylons contains operations rooms.

The walls are 30 cm to 50 cm thick, increasing to up to 1.40 m in the area of the internally threaded columns and the rack ladder. The transverse exterior walls are 75 cm thick. The walls are to be constructed using climbing formwork.

4.1.4 Cable pulley girder piers

The cable pulley girder piers, which are rigidly connected with the cable pulley girders and the caisson well, transfer vertical loads from the cable pulley girders into the caisson well and also accommodate the counterweight guiding mechanisms. The outer piers stand on the wall of the caisson well, the others inside the caisson well. Because of the great difference in stiffness between the cable pulley girder piers and the other load-bearing elements, the piers act as articulated rods.

In order to shorten the effective height of the piers in the longitudinal direction of the lift, the piers are connected with each other in pairs, by two bars for each pair above ground level and over the height of the caisson well by a diaphragm wall. The piers at the western edge which are connected with each other support the eastern bearing of the canal bridge.

The piers are 54.15 m high (the outer piers are 53.15 m high) and 1.40 m thick. For architectural reasons, the outer sides of the piers have a negative inclination of 3° to correspond to the outer wall of the cable pulley halls. This is why their width increases from 4.20 m at the foot of each pier to 8.29 m at its top; in order to transfer the vertical load under the axis of the cable pulley mountings into the caisson well, the load transfer area is 3.30 m wide.

In the upper area, the cable pulley girder piers project 3.80 m upwards and 1.55 m towards the inside. For architectural reasons, the projection of the crane runway in the pylons is replicated in order to create a uniform appearance.

The cable pulley girder piers are constructed using climbing formwork with the same surface structure as the pylon walls.

4.1.5 Caisson well

The caisson well is constructed as a watertight concrete tank with a base that is 2.4 m thick and side walls that are 1.5 m thick at the top and up to 3.0 m thick at the bottom. In the area of the pylons, the caisson well is around 8 m wider than between the pylons. For drainage purposes, its surface is constructed in first-stage concrete with a slope of 1 % transverse to the longitudinal axis of the lift.

In order to avoid negative effects on the existing lift, the caisson well will be constructed in a pit that is impermeable to ground water. For this purpose, a mixed sheet pile wall with size 1000 I-beams and double-plank infill walling will be driven into the bedrock to a depth of over 22 m and anchored. To prevent uplift, slender piles at intervals of 2.5 m will be bored under water 17.5 m into the base of the caisson well from the base of the pit which is about 15 m below ground level. After this, a 1.2 m thick layer of underwater concrete will be laid. The shoring of the pit will be used to support the formwork for the caisson well and provided with leveling formwork so that the construction concrete has a uniform thickness.

4.1.6 Control room

Control room

The control room is located between the eastern pylons with its floor at 53.01 m above sea level. Its load-bearing structure consists of a 16 m long and 6 m wide single-span composite steel beam with a superposed steel frame structure. It has the same façade cladding as the cable pulley hall. Its windows are inclined in accordance with the regulations for lock control rooms. Light partition walls with sound insulation in accordance with DIN 4109 separate the individual rooms. Like the cable pulley halls, the inclined pent roof is covered with insulated profiled panels. A visitor bridge crosses the caisson space beneath the control room.



Figure 6. View from the control room

4.1.7 Visitor galleries, walkways and bridges

The visitor galleries, walkways and bridges also serve as escape and rescue routes.

From each walkway along the canal bridge, a 2.6 m wide walkway at 38.75 m above sea level leads to the western pylons on the north and south sides. The walkways are supported by the canal bridge, by side brackets on the cable pulley girder piers and by the pylons.

The visitor walkways are at a height of 49.95 m above sea level in the interior of the structure above the caisson and extend along the cable pulley girders with a width of 2.1 m; on the outer side, between the pylons and behind the lattice girders, they are 2.8 m wide. Three bridges 3.0 m and 3.5 m wide span the caisson space between opposite pylons and at the east end.

4.2 Caisson

The lift caisson is a self-supporting structure with a load-bearing cross-section consisting of the operations walkways, the side walls of the caisson and the caisson floor. Cross beams and longitudinal ribs stiffen the cross-section. The cross beams are connected at both ends by longitudinal beams to which the counterweight cables are secured. The reinforced cross beams in the area of the caisson quarters transfer the imbalance loads into the load-bearing structure via the caisson safety system. The drives that run through the pylons are located in this area at the sides of the caisson. Machine housings protect the drives.

The specifications on the use of the lift result in an overall caisson length of 125.5 m, a width of 18.3 m in the area of the counterweights and of 27.9 m in the area of the drive housings; the construction height in the area of the counterweights is 6.3 m. In the area of the caisson safety system, the cross beams are 2.5 m high, resulting in a construction height in that area of 7.5 m. The operations walkways along the sides at the top of the caisson are 2.0 m wide; those in the area of the ship arrester equipment are 0.6 m wide and those at the height of the caisson base are 1.1 m wide.

During motion, the caisson is guided in transverse and longitudinal directions in such a way that it moves at equal distances between transverse guides.

While moving into or out of the caisson, ships cause fluctuations in the water level. In order to reduce the resulting loads on the drives, the caisson is secured by a caisson locking mechanism when it is at the docking points. This locking system is designed for a caisson imbalance corresponding to a water level fluctuation of 25 cm. A latch design is envisaged which is secured to the caisson and locks by means of a travelling counterpart (locking bar). To protect the locking mechanism from damage in the event of greater imbalance, it yields when overloaded so that the caisson begins to move. The rotary locking bars of the caisson safety system then engage with the internally threaded columns.

Swivel-radial gates close off the caisson at both ends. When open, they are rotated into niches in the floor, and for inspection purposes, they can be rotated upwards out of the water. Their upper edge is 5.0 m above the caisson floor so that their freeboard is 1.0 m. The gates are moved by two electric jacks, each with 650 kN drive force.

A cable-arrester facility protects the gates against ship impact.

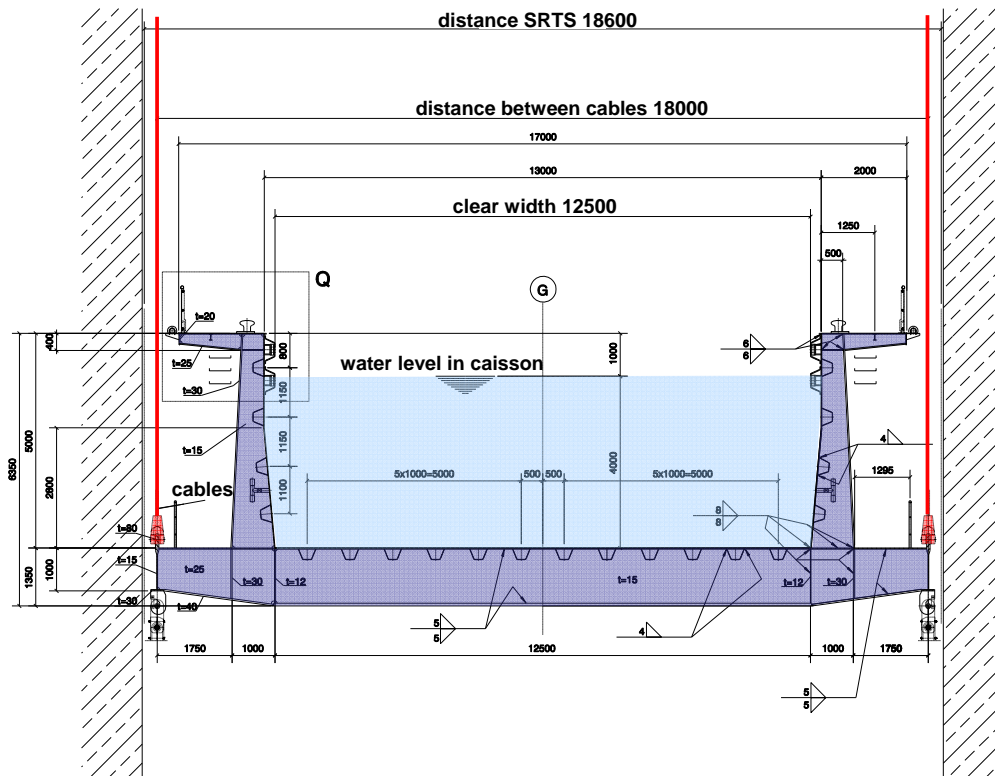


Figure 7.

4.2.1 Caisson drive

The lift caisson is driven from four points. The drives are located on both sides of the caisson in each of its four quarters, and are configured as rack drives with rack and pinion gearing. At each drive station, the drive machinery consists of three-phase asynchronous motors, electrohydraulically ventilated main and holding brakes (each independent of the others) and the main gearboxes. The two main gearboxes in each drive station drive the pinion gear that is guided by trolleys onto the rack ladder from both sides.

Each drive station has a power rating of around 320kW. It is designed in this way so that lift operation can be maintained in the event of failure of one drive.

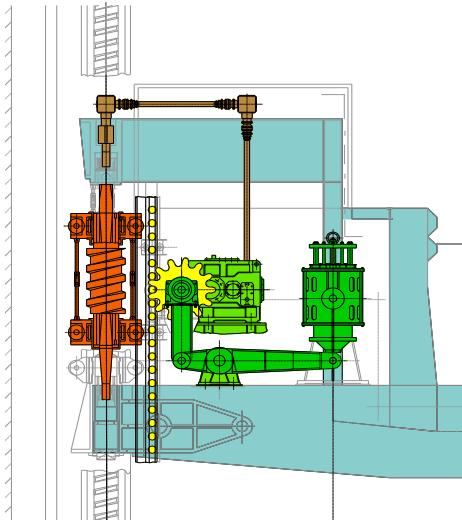


Figure 8. Caisson drive and safety system

Each rack ladder, which is anchored in the concrete of the respective pylon, has a clear width of 570 mm with intervals between bolts of 376 mm. The pinion that engages in the ladder has a pitch circle diameter of 1556 mm. It is supported by a spring assembly system.

To synchronize the four drive units, there is an electronic synchronization monitoring and control system, as well as mechanical synchronous shafts that run continuously. The mechanical synchronous shafts are so pliant that the electronic control system retains a sufficiently large range of control. The mechanical shaft system has two functions:

- ensuring synchronicity of all drive stations in the event of malfunctions of the electronic synchronous control system in the drives
- enabling operation of the ship lift to continue for a time in the event of failure of the drive force at one drive station.

4.2.2 Counterbalancing system

The counterbalancing system consists of the cable connections to the caisson, the cables, the cable pulleys and their bearings, the bearing blocks, the cable connections to the counterweights, the counterweights themselves, counterweight arrester and guide frame, with the frame guideway on the pylons and on the cable pulley girder piers, as well as the counterweight balancing and the cable weight balance chains.

4.2.3 Cables

Each cable carries a counterweight or a cable weight balance chain. Pre-stretched, galvanized parallel lay cables were selected which are not of non-twisting type and are arranged in pairs. A right-lay and a left-lay cable run over each double cable pulley. The cable ends are specially cast in fork-type cable sockets, and connected to the caisson and counterweights via the fork-type sockets with releasable bolted connections. The lengths are accurately adjusted by means of turnbuckles on the counterweights.

The diameter of each cable is $d = 60$ mm, and its nominal wire strength is 1770 N/mm².

The cables are laterally deflected by up to 1.5° , the primary cause for this being the different temperature expansion of the caisson and the load-bearing structure.

4.2.4 Cable pulleys

The double cable pulleys are supported by blocks on the cable pulley girders in the cable pulley halls at average intervals of 1.5 m. These intervals allow service personnel to pass between the cable pulleys and thus simplify their maintenance. The diameter of the pulleys is 4 m; this large diameter is expected to result in a long usable life for the cables. The bearings of the cable pulleys are located so that they are easily accessible from the side from an intermediate floor. The cable pulleys can be lifted so that the bearings or the cables can be replaced without opening the roof. However, should it become necessary to replace a cable pulley, the roof can be opened and a 300 t mobile crane can lift each cable pulley out individually.

4.2.5 Counterweights

There are seven counterweight groups on each side between the cable pulley girder piers and the pylons. Each group consists of ten to twenty counterweights which are held together by an arrester frame. In the event of failure of a cable, the arrester frame transfers the load to the intact cables and thus prevents the weight from falling.

The 2.5 m wide and 7.1 m high counterweights are constructed as 68 cm thick dense concrete discs except at the edges of each group where they are 31 cm steel disks. The weights weigh around 40 t; the exact mass can only be determined by the manufacturers after completion of implementation planning. Using balance weights in niches under the counterweights, the weights of the individual counterweights can be increased by up to 2 t.

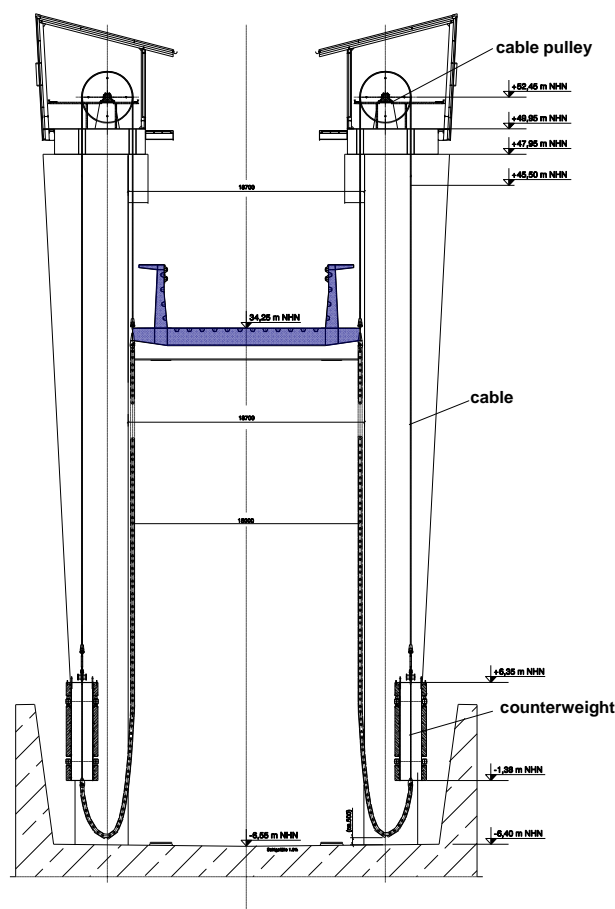


Figure 9. Cross-section of the lift showing caisson, cable pulleys, cables and counterweights

4.2.6 Counterweight guidance

The counterweight arrester frame is guided at right angles to the lift by fixed and spring-supported pulleys and lengthwise by means of slider shoes. The guide rails are secured to the pylons and to the cable pulley girder piers.

4.3 Caisson safety system

The caisson safety system prevents overloading of the pinion and the brakes of the drive by securing the caisson by means of four rotary locking bars in four internally threaded columns. This operating situation constitutes an emergency and can occur if the caisson is emptied or over-filled. Planned emptying of the caisson also takes place approximately once a year for inspection and repair purposes.

The internally threaded columns are 41.6 m long, with a split internal thread anchored inside the pylons, and consist of several sections. The rotary locking bars, connected with the caisson via pendulum supports, have 4 thread pitches, a height of 3 m and an outer diameter of 1.08 m. Each weighs around 10 t. At right angles to the caisson, the four axes of the internally threaded columns are 30 m apart, and lengthwise along the caisson they are 69.85 m apart.

During normal operation, the caisson drives rotate the rotary locking bars freely via a coupled shaft system. Up to the point of settlement on the internally threaded columns, the force on the pinion corresponds to the external force on the spring housing, taking leverage into account. Taking into account friction, accelerating/braking forces and wind forces and a water level in the caisson of less than 0.08 m, the force on the spring housing is less than 200 kN.

The pre-loading of the springs is selected so that the pinion does not start to deflect against the spring until a force of 200 kN is exceeded. When spring deflection in one spring housing starts, the 4 caisson drives are stopped. The force on the pinion then increases in accordance with the spring characteristics. When the force on the pinion reaches 990 kN, the rotary locking bar settles in the internally threaded column and absorbs the differential loads until the maximum imbalance load has been applied and a force of 1090 kN therefore acts on the pinion. The force acting on the pinion is continuously measured, both while the caisson is stationary and while it is moving.

In the event that the maximum operating force on the pinion is exceeded, the drive is switched off and the pinion deflects against the spring.

4.4 Control system

The lift control system consists of an automation system and an operating and monitoring system.

The lift drives are automated with programmable logic controllers (PLCs) and sensors that determine the state of the facility. Each drive unit, for instance each caisson gate, has its own PLC. The control systems are connected with each other and with the master PLC via a bus system. In the event of failure of the bus system, each unit can still be operated individually.

In order to be able to check during the planning stage that the planned control system is compatible with the planned machinery, a virtual control model of the lift has been set up. This model includes the drives (actuators), limit switches, measurement equipment and monitoring units (sensors). This makes it possible to simulate the planned lock passage procedure as well as breakdown or malfunction of one or more elements of the control and sensor systems. The reactions to the simulated malfunctions are analyzed and the conditions arising as a result of these reactions are evaluated. If it becomes apparent that unacceptable conditions can occur, the machinery must either be controlled in a different way or fitted with different control system elements and sensors or other protective measures must be taken.

Classic digital control models show curves, sensor indicators, switch positions and other logical connections. The condition and the reactions of the facility can usually only be recognized quickly and effectively by control system technicians. In order to improve communications between the control system engineers, the planners of the building and the operators of the facility, this model represents the lock operation procedure in the form of a computer animation. The pictures show the processes and responses in sequence in the set times and make it easier for personnel who are not control system technicians to follow the sequence of events and recognize any incompatibilities.

At a later stage the testing model will be developed from this model for planning purposes. This will make it possible to check the programs developed for the control system before the facility has been constructed or its hardware installed. It will also be possible to analyze the reactions of the lift to defects which would cause damage if they were included in tests of the real lift.

The model will be retained after completion of the lift. It can be further developed for use during training of the operating and maintenance personnel, and can also be used to estimate the effects of modifications to the control or sensor systems.

4.5 Lower pound docking station

The lower pound docking station is a concrete structure connected directly with the east side of the caisson well with its pound gate and an auxiliary gate serving as an inspection closure facility. It is 20.85 m long and up to 26.80 m wide; its usable width for shipping is 12.5 m and its platform lies 3.05 m above sea level. The rooms for the drives of the two gates are located in its sides together with the clearance evacuation and reversing equipment. This equipment is used to correct the water level in the caisson if necessary, and before the lift caisson is undocked, it is used to empty the water from the gap between the caisson gate and the docking gate into the lower pound via a pipe system. The rooms are accessed via outlets from the lock platform.

Like the caisson gates, the pound gate is a swivel-radial gate. It is identical in structure to the upper pound gate. The upper edge of the retaining wall is 2.35 m above sea level and the sill is 2.8 m below sea level. The gate is fitted with a spillway. In the event of high water at 2.70 m above sea level, water would flow over the lower pound gate, which means that the auxiliary gate must be closed under such conditions. The auxiliary gate is to be constructed as a miter gate.

5. Canal bridge

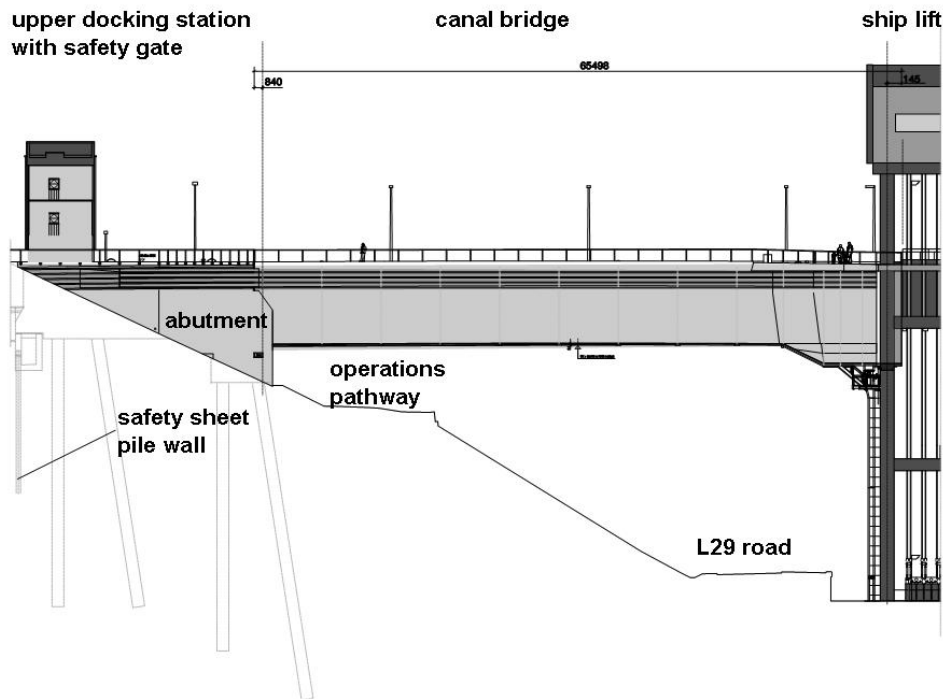


Figure 10. Canal bridge

The 65.5 m long canal bridge connects the lift with the upper basin. Like the lift caisson, it has a usable width of 12.5 m.

Like the lift caisson, it is closed on the lift side by a swivel-radial gate which is protected by a cable arrester facility. The gate thus forms the eastern end of the summit reach of the canal. The clearance evacuation and reversing equipment is located in the eastern head area of the canal bridge, in addition to the gate drives.

On the right and left of the canal bridge there are side paths which can be used by maintenance vehicles. This makes it possible to lift the heavy sliding gates of the caisson evacuation equipment through openings using a truck-mounted crane on the canal bridge and to take them away for repair purposes. For inspection purposes, the canal bridge can be viewed from the side paths using special vehicles that can reach underneath it, as is customary for motorway bridges.

In addition to the canal bridge, the 25 m long and up to 31.5 m wide western abutment supports the safety gate with its gate drive housings. The gate is closed for scheduled emptying of the canal bridge, or if in an emergency, there is a risk of water flowing out of the summit reach of the canal via the canal bridge or the lift. A hawser capture cavity with a volume of 75 m³ is integrated into the base of the abutment. To ensure that the abutment reliably directs the horizontal loads from the canal bridge into the site foundations when the pound gate is closed and the clearance is empty, the abutment has foundations consisting of bored piles embedded in the solid boulder clay. For this reason, the 28 piles with a diameter of 1.2 m are 24 to 30 m long.

On the headwater side, the clay sealing layer of the upper basin and the safety bulkhead with an inspection walkway connect with the abutment. The connection with the canal sealing consists of a 3 m thick clay wedge. The integrity of the connection of the safety bulkhead with the abutment can be monitored from an inspection walkway which crosses the canal on the eastern side under the abutment.

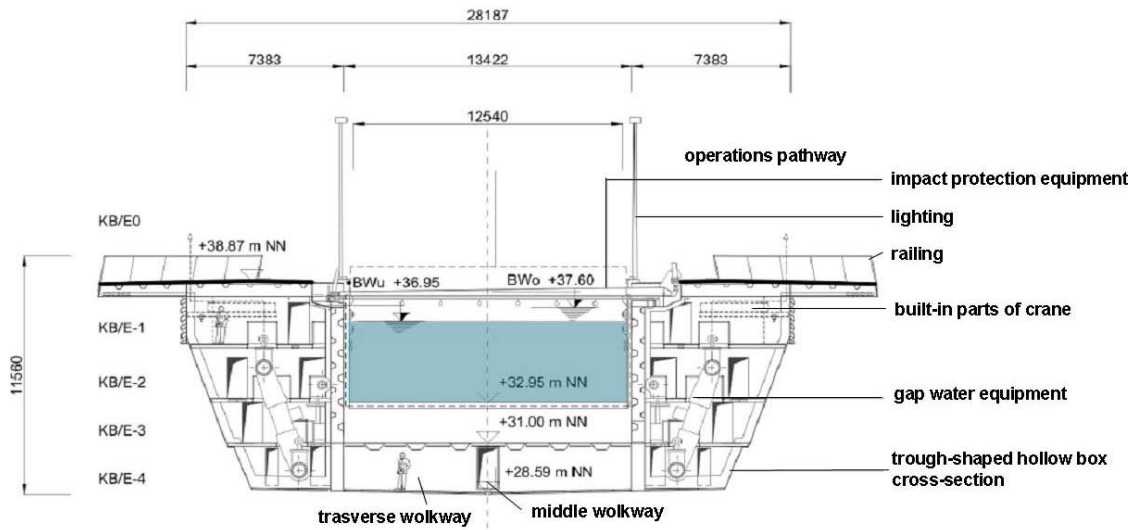


Figure 11. Cross-section of the canal bridge

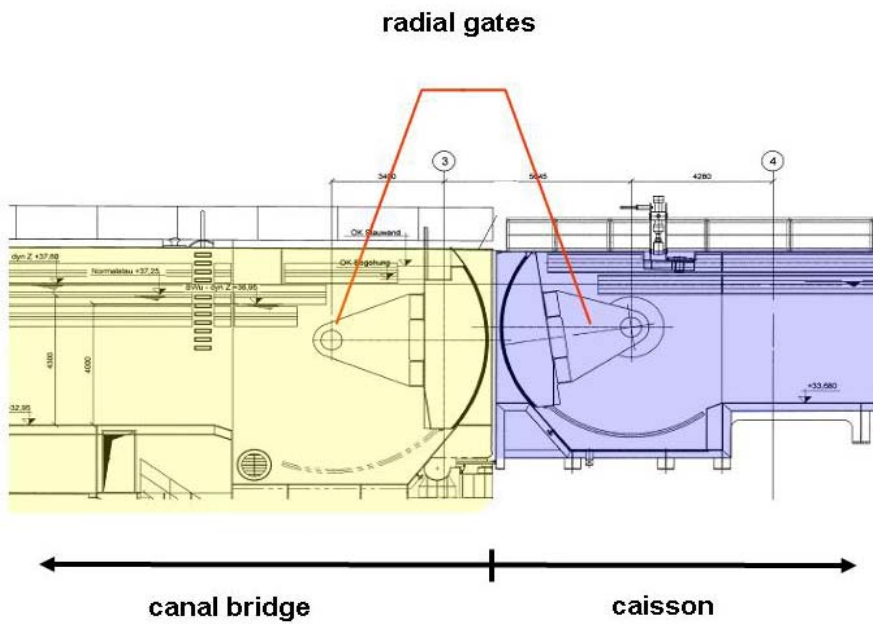


Figure 12. Radial sectional gates between the canal bridge and the caisson

6. Upper basin

The access route to the new lift branches out of the basin of the existing lift with a radius of 2000 m. The new basin has a water level width of 46.5 m, a water depth of 4 m under the lower operating water level and is 440 m long. Its base is provided with a 40 cm thick clay sealing layer, filter mats and a 60 cm thick revetment. The banks on the north and south sides are secured by sheet pile walls and serve as waiting positions on both sides. On the south side, the two basins are separated by a mole which is around 110 m long and 9 m wide.

The top level of the basin lies around 32 m above the countryside of the Oder lowlands. At the Hohensaaten end, the dam height reaches around 36.5 m. To the north, the dam embankments extend up the decommissioned flight of locks.

To ensure the stability of the dam in the event of failure of the sealing, in its eastern section a safety sheet pile wall is to be inserted into the boulder clay as a second sealing layer. It begins in the vicinity of Lock III, runs parallel to the bank up to the abutment sheet pile wall, crosses the abutment and continues for another 50 m or so back to the west. Its sheet sections are between 15 m and 30 m long.

The new basin will be empty during construction. A cofferdam will be constructed in front of the existing dam in the existing basin. The canal sealing layer including its securing elements will be inserted into the dry sheet pile cavities of the cofferdam. Not until the body of the new dam has been constructed, the sealed basin excavated up to the foot of the dam of the existing basin and the safety gate has been closed will the existing dam be removed under the protection of the cofferdam, and the sole of the canal connected with a provisional cofferdam between the new basin and the existing basin. When the canal bridge is completed, the upper basin will be flooded and the cofferdam removed. The sheeting planks of the cofferdam will be burnt off above the sealing layer.

During construction, the ground water levels which have been monitored for 10 years will be continually checked and supplemented by further measurements. To be prepared for possible accidents, appropriate emergency plans will be made and emergency materials kept on hand.

7. Lower basin

The lower basin flows into the lower basin of the existing lift in the area of the Hohensaaten terminus. Both banks will serve as waiting areas, the north being 440 m and the south 360 m long. The northern bank is secured by a revetment. Mooring posts will be provided at 30 m intervals. The southern side will be secured by an anchored sheet pile wall.

8 Surroundings

8.1 Visual appearance

The appearance of the new lift was developed in close cooperation with the Federal Waterways and Engineering Research Institute (BAW) which had a decisive influence on its architecture. The design is oriented towards the functionality of the structure. The objective of the design exercise was the visualization of the lifting procedure and the distribution of tasks amongst the components of the load-bearing structure. Integration into the surrounding landscape is achieved by minimizing the structural mass, thus creating transparency. The architecture underlines the role of the ship lift as a self-assured contemporary engineering structure. The design respects the old ship lift built in 1934, but at the same time, it aims to demonstrate the high levels of engineering competence at the beginning of the third millennium.

8.2 Visitors

The existing ship lift is a tourist attraction in the region north-east of Berlin and has up to 150,000 visitors each year. The construction process and the new lift itself are also expected to attract a great deal of public attention.



Figure 13. Bird's eye view of the lifts

A visitor concept has been created to satisfy the demand for information and for a space for experiences, and also to control the flow of visitors. In the new lift, visitors are not led around a gallery on the outside of the building, but through the building itself, thus bringing them as close as possible to the technology. The routes are designed so that visitors have no negative effect on the operation of the lift. In the event of large-scale maintenance work, visits will have to be restricted. Visitors with limited mobility can use a lift to reach the level of the canal bridge and the cable pulley halls.

The visitor concept focuses on the information center, which, after a number of locations were considered, has been built on the existing parking area south of the existing lift. This location is close to the visitor routes for the lifts. A permanent exhibition in the information center provides information about the technical data of both lifts. Visitors are also informed about the inland waterways as a reliable, cost-effective and environmentally friendly means of transport and about the inland waterway transport system, its maintenance and administration.

9. Participants in the project and progress of construction to date

As preparatory measures, electrical cables were re-routed and parts of the Niederfinow municipal building yard were relocated in 2005. In March 2006, invitations to tender for the necessary demolition tasks were sent out. In parallel with this, the contract documents for the construction of the ship lift were produced and preparations for the awarding of contracts were made.

On 16.05.2008, the contract to construct the new ship lift was awarded to the Neues Schiffsbauwerk Niederfinow consortium consisting of Bilfinger Berger Ingenieurbau GmbH, DSD Brückenbau GmbH, Johann Bunte Bauunternehmung GmbH & Co. KG and Siemag M-TEC² GmbH. The consortium started work in summer 2008.

The most important participants in the project are listed in the table below.

Table 3 Participants in the project

Role/task	Name
Owner	Wasserstraßen-Neubauamt Berlin
Study of alternative solutions	Krebs und Kiefer SBE Magdeburg Germanischer Lloyd
Design planning	Lahmeyer International/Hydroprojekt with Ingenieurbüro Rapsch und Schubert, Werner Sobek Ingenieure, DriveCon
Inspection of structural design	Prüfgemeinschaft (inspection consortium) Niederfinow consisting of Krebs und Kiefer, Germanischer Lloyd, SBE Magdeburg
Advice to owner, site foundations and design	Bundesanstalt für Wasserbau (BAW)
Construction	Bilfinger Berger Ingenieurbau GmbH, DSD Brückenbau GmbH, Johann Bunte Bauunternehmung GmbH & Co. KG Siemag M-Tec ² GmbH

9.1 Construction pit

The construction pit consists of a simply anchored soldier pile wall. The longest beam is 23.80 m long and the anchoring system consists of 429 strand anchors. The greatest anchor force is 673 kN. A 1.30m thick concrete sole at a depth of ca. 12 m seals the construction pit against penetration by ground water. For the construction of the sole, in March 2010, 8 318 m³ of underwater concrete were pumped non-stop into the construction pit in a period of 80 hours. The sole of the construction pit is secured against uplift by 1034 uplift piles known as micropiles. These are fixed into the bedrock under the concrete sole to a depth of 17.50 m and are arranged in a grid measuring 2.5 m x 2.5 m.

During concreting, the water in the construction pit became enriched with calcium hydroxide ions as planned and reached a pH value of 12.4.

Because of this, the water had to be “neutralized” before it could be pumped out. In close agreement with the water authorities, a procedure was used in which CO₂ gas was introduced using spraying equipment on the sole of the construction pit.

After the water had been pumped out of the construction pit and a few leaks had been sealed, a 35 cm thick layer of drainage concrete was laid in July and August 2010. This consists of large-pore water-permeable single-sized concrete and is intended to absorb any residual water that penetrates the pit.

9.2. Upper basin

Before the construction pit could be excavated, extensive earthwork was necessary and the upper basin had to be constructed together with the canal with which it is connected (see also Chapter 6). This work was done from the end of 2008 until summer 2010. Figure 14 shows the new elevated canal section with the new basin and the construction pit which has not yet been pumped empty. The four large tower cranes can also be seen; they give an indication of the dimensions of the new lift.

9.3 Caisson well

Construction of the formwork for the caisson well started in summer 2010. In a first step, it is constructed using filigree slabs that lean against the construction pit wall as lost formwork. The reinforcement of the caisson well sole will be laid from December 2010.

9.4. Outlook

Assuming that construction proceeds smoothly, the new Niederfinow ship lift will go into operation in 2014. By then, ca. 53 700 m³ of concrete, 8 900 t of reinforcing steel and 6 000 t of steel will have been used. A total of ca. 396 000 m³ of earth will have been moved. The construction costs are estimated at ca. 285 million €.



Figure 14. Construction site in August 2010