World's largest sea lock

Noordersluis in IJmuiden replaced by a new gigantic concrete lock

In IJmuiden, located at the mouth of the 27 km long Noordzee-kanaal that links Amsterdam and its port with the sea (fig. 1), the Ministry of infrastructure and the Environment is building the world's largest sea lock. The extremely tight construction site and the tight schedule add to the complexity of the project. The gates in the new lock will reach almost 8 m above the current water level, thus providing defence against rising sea levels. The enormous lock will be made out of 290 000 m³ of concrete.

IJmuiden has a long history as gateway to the Noordzeekanaal for sea going vessels. In 1876, the Noordzeekanaal was opened with the still operational Kleine sluis (Small lock) and Zuidersluis (Southern lock). The rapid development in the early years was crowned by the opening of the Middensluis at the end of the 19th century. At that time the Middensluis was the largest lock in the world. The construction of the Noordersluis in 1929 completed the lock complex in IJmuiden. With a length of 400 m, width of 50 m and depth of 15 m it became the largest lock in the world then.
Replacement of the Noordersluis is necessary after being in use for nearly a century. A new and larger lock should improve

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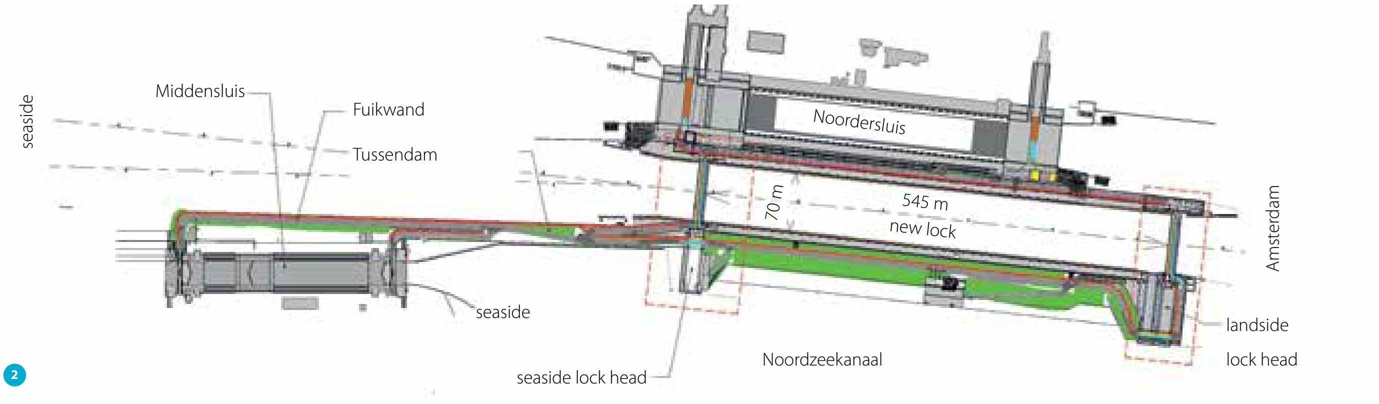
1 Impression of th new lock and existing Noordersluis (to the right)
credits: ZUS
2 Overview of the new lock situated between the existing Noordersluis en Middensluis
3 Typical cross section lock chamber.



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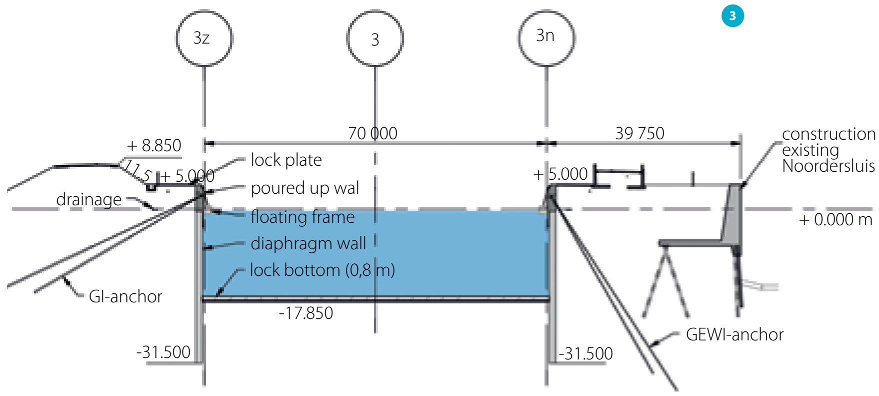
accessibility to the port of Amsterdam and strengthen the economy of the region by offering a tidal independent access for vessels constantly increasing in size. The new lock will be 70 m wide, 500 m long and 18 m deep (a typical cross section is shown in fig. 3). This lock will be the largest in the world and is situated just in between the existing Noordersluis and Middensluis, which are two locks currently in use (fig. 2). Continuous operation of these locks has to be guaranteed during construction of the new lock, thus requiring numerous considerations for the impact of construction on the existing locks.
The lock complex, besides having the obvious navigation facilities, features multiple other functions. A key feature is the primary flood defence. Water management (management of the North Sea Canal), passing road- and water traffic and environmental objectives (fish migration) complete the main functionalities of the new lock.

The walls of the new lock are primarily constructed as anchored diaphragm walls. The execution of this type of structure has a lot of advantages compared to the execution of steel combi-wall or sheet pile walls with respect to (sound) nuisance and vibrations which could influence the stability of the existing locks and of the primary flood defence.

The new locks will be provided with rolling steel gates that are parked in a gate chamber when the gate is in open position. The seaside upper lock head will have one gate chamber. The lower lock head will have two chambers, one for the operational gate and an additional chamber for a spare gate. The concrete structures holding the gate chambers have an area of 80 × 26 m² and 80 × 55 m² and a height of 30 m.

The contract for the design, construction, finance and maintenance during 26 years was awarded to the combination OpenIJ, consisting of BAM-PGGM, Volker Wessels and DIF. Design of the lock started in September 2015 and construction in 2016.



Functioning and stability of the Noordersluis and Middensluis

The realization of this large lock in the lock complex forms a risk for the stability of the Noordersluis and Middensluis. The lack of space in the complex means the construction site will be very close to these existing locks.

The lock complex has a complicated soil profile due to its history with liquefactions and major breaches. Rijkswaterstaat has undertaken extensive ground investigations as part of the preparation for the project. This resulted in limitations on the horizontal and vertical deformation at the top of the existing locks, limitation of vibration of the existing structures and limits on ground water levels and groundwater pressures near the existing locks. With the obligations to monitor deformations and ground water pressures in time, it is possible to construct the new lock at the prescribed location with a minimum risk of failure of the existing locks. For example: the horizontal displacement of the existing locks is limited to 10 - 30 mm. This is feasible with the use of diaphragm walls.

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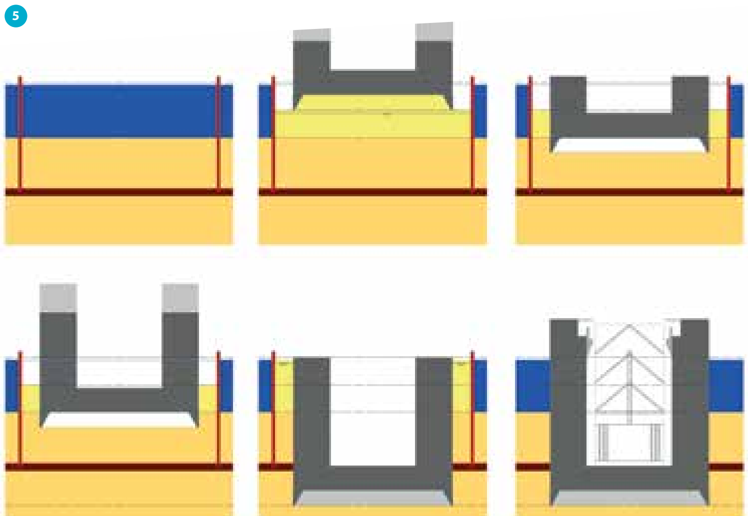

4 Digging of the diaphragm walls

credits: Ko van Leeuwen

5 Installation of door chambers by the pneumatic caisson method

OpenIJ has carried out further research in order to determine the influence of the selected construction methods and validate the design. Field trials were undertaken to validate the prediction models used for vibration and settlement. The validation models make it possible to take effective mitigation measures, which include decreasing embankment slopes, installing rock layers and drainage.

The design of the OpenIJ is characterised by a number of execution methods which were chosen to minimise the impact on the existing locks. As much as possible, the vibration-free diaphragm wall method will be applied for the construction of the chamber walls. The two chambers for the rolling gates are constructed on ground level and installed using the pneumatic caisson method. On locations where diaphragm walls are not possible, sheet piling or combined walls will be necessary. When the impact on the existing locks is too large, sheet piles will be applied in a cement-bentonite slot and tubular piles for a combined wall will be drilled.

Flood defence system

The lock complex in IJmuiden fulfills the function of primary flood defence. The existing flood defence system and flood defence formed by the new lock must be assured at all times.

In the preparation phase Rijkswaterstaat has undertaken research on the requirements for the primary sea defence system for the new lock, taking into account the possible sea level rise due to climate change. The most important requirement is the retaining height of 8.85 m + NAP for the flood defences with exception of the sea side lock gate which must meet a retaining height of at least 7.8 m + NAP. This reduced retaining height results in an additional volume of waterhazard. Considering the complete system of flood defence, this additional volume is limited, because the width of the lock gate is only a very limited part of the flood defence line. Considering the local situation, it is checked that the water storage capacity of the Noordzeekanaal is more than sufficient to deal with this volume.

Part of the contract of Rijkswaterstaat, amongst other things, is providing sufficient robustness of the flood defence system. OpenIJ created this additional robustness by using the flood defence height of 7.8 m NAP for both the seaside and landside gates and applying walls along the lock chamber with a retaining height of 8.85 m NAP. As one gate will always be closed there is always a closed flood defence, even in the unlikely event that the seaside gate cannot be closed during a storm surge.

6 New sea lock under construction
credits: Topview Luchtfotografie

Diaphragm wall

Because the new sea lock will be built between the Noordersluis and Middensluis, a large portion of the Middensluiseiland has to be removed. This is necessary for the lock itself but also for the approach channel on the seaward side.

Since the Middensluiseiland is part of the flood defence, a structure must be built west of the new lock to facilitate the approach to the new lock as well as to protect the inland against high water levels. This structure, the so called Fuikwand and Tussendam (fig. 2), connects the Middensluis with the new lock. Additional robustness has been provided by the use of diaphragm walls for this structure.

The Fuikwand is an anchored diaphragm wall and the Tussendam is a coffer dam consisting of a diaphragm wall on the seaward side and a combined wall at side of Noordzeekanaal. A diaphragm wall has been selected here in favour of a steel sheet pile or combined wall because of possible ship collision. This comprises all types of collisions, including the governing collision with a bulbous bow. In case of a collision the damage of a diaphragm wall will be less than that of steel sheet pile or combined wall. A collision could result in a hole in a sheet pile or combined wall through which sand from behind the wall could run away causing damage to the dam.
The construction of the diaphragm walls started in January 2017 (fig 4).

Gate chambers

At the end of 2016, sheet piling and tubes were installed to create the temporary building pit for the construction site of the gate chambers. To construct the chambers for the seaside and landside gates, a dry working level will be created inside the building pit at 5 metres below the current water level (fig. 5). At this elevation the cutting edge of the pneumatic caissons will be build, formed by concrete triangles 2.5 m high. On top of the cutting edge the 4 m thick floor will be constructed, followed by the lower section of the up to 7 m thick walls. This first part of the caisson will be lowered by 5 m by the pneumatic caisson method. After reaching this depth the second stage of the walls is constructed and the structure is than lowered 13 m to its final depth. Use of the pneumatic caisson has the advantage that a building pit with heavy combined walls, heavy supporting frames and an anchored underwater concrete floor could be avoided. By doing so vibrations and noise could be minimized.

The IJmuiden sea lock is one of the so-called Connecting Europe Faciliting and is partly financed by the EU's CEF programme. At the moment construction of the lock is in full swing. The lock should, after a period of testing, be operational by the end of 2019. ☒