Construction of the Deurganckdok in the Port of Antwerp, Belgium

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After the completion in 1996 of two container terminals situated on the river Scheldt in the port of Antwerp, new container handling capacity was needed to accommodate the fast growing container traffic in the port of Antwerp. Therefore a new tidal dock, the ''Deurganckdok'', was constructed, consisting of about 5 kilometres of new quay walls at the left bank of the river Scheldt, surrounded by almost 300 ha of terminal area. The first phases of the terminals situated at the Deurganckdok, operated by PSA and P&O Ports, officially opened in 2005.

The quay walls were constructed as a large L-shaped reinforced concrete wall with a height of 30 meters, fully constructed in a dry excavation. The paper will give a description of the different construction phases of the tidal dock (starting from the lowering of the groundwater to the dredging of the dock). Also a motivation of the choice of this type of quay wall will be given by a comparison of this type of quay wall with another type that was considered, namely an unreinforced massive concrete quay wall. To motivate this choice, the two quay wall types will be compared with different criteria (like stability, deformation behaviour, durability, resistance to impact, impact to neighbourhood, . . .). The paper will also give an overview of the different cost components of the construction cost.

1. General Description of Quay Wall Type

The quay wall type that was chosen for the construction of the Deurganckdok was a large L-shaped reinforced concrete wall with a height of 30 meters, fully built in a dry excavation.

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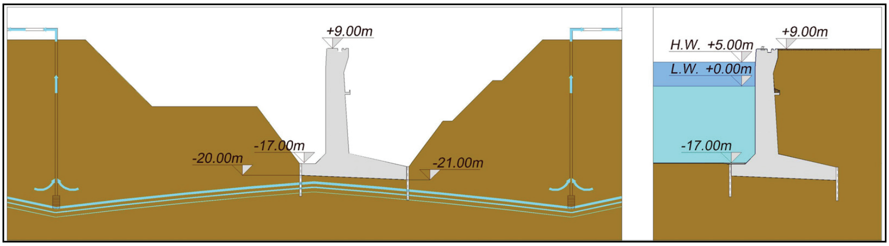


Fig. 1. L-wall during construction + L-wall after completion.

The most important characteristics and design criteria for the wall are the following:

- The water level on the river Scheldt in the Antwerp region has a tidal range of about 5 meters. The water depth taken into account during the design is 17 meters at the mean low water level.
- The retaining height of the wall is 26 meters.
- A draining system is incorporated to prevent excessive water pressure behind the quay wall.
- Maximal surface load: 60 kN/m^2.
- Vertical crane load: 800 kN/m.
- Pull force on bollards: 1500 kN.
- In front of the quay wall, an erosion protection is installed to prevent erosion of the harbour bottom.

2. Description of Construction Phases

After lowering the groundwater level at the construction area with ca. 26 meters, a large excavation is made to make it possible to build the quay wall in a dry way (Fig. 2). To reduce the influence to the neighbourhood from the lowering of the groundwater, the groundwater was re-infiltrated in the bottom. The sand that is excavated from the deeper layers is used to refill the excavation behind completed parts of the quay wall (see further in Fig. 6).

When the level of the future dock bottom is reached, sheet piles are driven into the ground (Fig. 3). These sheet piles, which can be seen on the cross section of Fig. 1, have two different functions:

- prevent erosion due to piping beneath the quay wall;
- prevent sliding of the quay wall.

After installation of the sheet piling, the excavation continues between the sheet piles until the foundation level of the quay wall is reached.

Next step is the construction in reinforced concrete of the foundation base of the quay wall (Fig. 4). Depending on the local soil conditions, the width of this base varies between 24 and 26 meters. The concrete part of the quay wall is made in modular parts of 20 meters, following the ‘‘lead and drop’’ method. Starting from

Fig. 2.

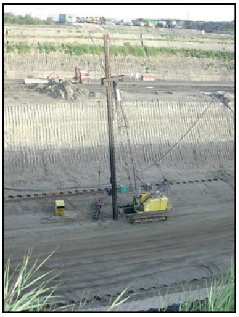


Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

the lowest point of the quay wall, up to the top, a rubber joint strip is placed to prevent loss of sand through the joints.

On top of the foundation base the vertical part of the quay wall is constructed, also in parts with a length of 20 meters (Fig. 5). Since the steel reinforcement meshes and bars are too large to be transported, they are bent, woven and welded in situ. The reinforcement meshes and huge formwork panels are moved by a rail-mounted gantry crane. On top of this gantry, a platform is installed with vibration equipment for compaction of the concrete. At the western wall, the vertical part was concreted in a single section of 1600 m^3 during 2×8 hours. The concrete (specifications: C25/30) was made by a concrete plant at the construction site.

The excavation behind the finished parts of the quay wall is refilled only with sand with good geotechnical properties (Fig. 6). The refilling is executed in layers of 30 cm thickness, and the sand is being compacted to ensure that the assumptions made during the geotechnical design of the quay wall are met. The level of compaction plays an important role in the stability of the construction and in the expected settlement behaviour.

Also the top phase of the wall was built with the ''lead and drop'' method (Fig. 7). In this phase, the necessary mooring equipment is included (bollards, fenders, . . .). Also provisions are made to enable the future terminal operator to use the quay wall as a foundation for the waterside crane rail.

To take full advantage of the dry excavation, part of the sand for the refilling of the excavation is taken in front of the quay wall, by excavating an area of about 30 meters. This makes it possible to install an asphalt layer in front of of the quay wall, serving as an erosion protection (Fig. 8). This method is by far less expensive then installing an erosion protection in a later phase, beneath the water level.

After finishing the quay walls, dredging can start. During the first phase of the dredging works, the embankment between the river and the dock was kept untouched (Fig. 9). This made it possible to dredge with a fixed water level, without any tidal influence. The dredged material was used for hydraulic landfill at the future terminal areas and to fill up part of the existing Doeldok.[1]

3. Cost Structure of Quay Wall Type

The total contstruction cost of the L-shaped quay wall in reinforced concrete is about 38.360 EURO for 1 meter of quay wall. The following remarks are important

Table 1. Construction cost breakdown.

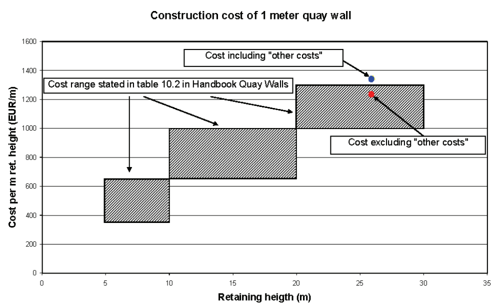
	Cost per meter of quay wall	
Cost component	In EURO	In % of total cost
Lowering of groundwater and protection measures	4.570	11,91
Earth works	4.760	12,41
Concrete	15.040	39,21
Steel reinforcement	5.145	13,41
Sheet piling	2.115	5,51
Mooring equipment	625	1,63
Fendering	2.200	5,74
Erosion Protection	935	2,44
Other(*)	2.970	7,74
Total	38.360	100

(*) Other costs: mobile offices, rental of jeeps for transport on construction site, temporary employment of secretaries, communication to public, cost of fixed construction site equipment (concrete plant, . . .), etc.

to compare this figure with other data:

- Cost is based on real construction costs.
- Cost is stated with price level of the date on which the contracts for the construction were tendered (period 1998–2002); influence of price evolutions during construction period is excluded.
- Dredging costs are excluded.

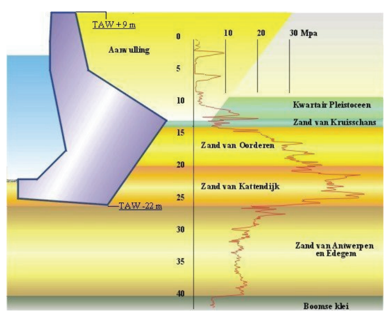
A break-down of the construction cost in its different components gives the result (Table 1).



In the Handbook Quay Walls,[2] presented at MTEC 2005, some indices are given for the estimation of the construction costs of quay walls in the Netherlands. To compare the cost of the L-shaped reinforced quay wall with these indices, the costs for fendering and erosion protection have to be excluded. The cost per retaining height (retaining height in this case is 26 meters) is then situated in the range between 1.240 EURO and 1.355 EURO, depending on whether or not the ''other costs'' are taken into account. This is a little bit higher than 1000–1300 EURO, the cost per retaining height stated in the Handbook Quay Walls for walls with a retaining height of 20–30 meter (graph 1). This difference can be explained by the fact that:

- The quay wall is designed for a tidal range of 5 meters.
- In the earth works, also some works are included which are not only connected with the construction of the quay wall (earth works on terminal area).

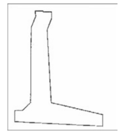
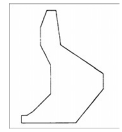
4. Alternative Quay Wall Types



During the planning phase, some other quay wall types were considered and compared using as most important criteria: stability & deformation behaviour, durability, resistance to impact, risk of sand loss through joints, cost, impact to neighbourhood during construction and experience in a tidal environment. After a first selection, two quay walls were selected for further study: the L-wall and the so called J-wall (see Fig. 10).[3] This J-wall is a wall in massive, unreinforced concrete, with a shape adapted to the local geology.

After study and comparison of both quay wall types, it was decided to chose the L-wall in reinforced concrete, in first place because of the established experience

Table 2. Comparison of L-wall and J-wall.

			
Stability & deformation	Due to the fact that the J-wall is supported at the back by a very hard sand layer, the deformation behaviour of this wall is better.		+
Cost	The J-wall is expected to be less expensive: – more concrete, but cheaper composition – less steel reinforcement – less earth works		+
Experience in tidal environment	The L-wall has already been used in a tidal environment in Antwerp. In the port of Antwerp, several kilometers of unreinforced concrete walls were built in the past, but never in a tidal environment.	+	
Other criteria	For the other criteria (durability, resistance to impact, risk of sand loss, impact to neighbourhood) both quay wall types have more or less the same performance.	=	=

with this type of wall. In order to make the J-wall more cost-effective then the L-wall, a different, cheaper (less cement) concrete composition had to be studied. Due to the lack of long-term experience with this concrete composition, the choice was made not to experiment on such a large scale project.

References

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2. CUR, Havenbedrijf Rotterdam N.V., Gemeentewerken Rotterdam (2005), *Handbook Quay Walls*, p. 469, table 10.2.
3. Cosyn, Baekelandt, Van Celst, Simons, Thibaut, Vandamme, Dedeyne and Vandemeulebroecke (2002), Development of an unreinforced concrete wall for deep water tidal docks in Antwerp, *PIANC 2002 30th International Navigation Congress*, Sydney (Australia).