Witteveen + Bos

Lynetten Aqueduct

Consideration of aqueduct for Margretheholm Harbour

Yacht Club Lynetten

19 May 2021

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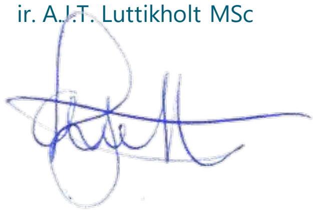
Initials	
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INTRODUCTION

1.1 General information

The Yacht Club Lynetten in Copenhagen have asked Witteveen+Bos to assess the feasibility of an aqueduct design in the Margretheholm harbour knowing the design, cost estimate and time schedule for an aqueduct prepared by Sejlklubben Lynetten. Witteveen+Bos answer is given in the following including the characteristics of aqueducts in general. By showing the design of some of the aqueducts constructed in The Netherlands the pros and cons will become clear. This should explain why in the last twenty years more and more aqueducts were built in favor of bridges. Were in the early years of aqueduct construction they were purely built to limit road traffic disruptions, the last 20 years the importance of leisure and recreational sailing has become more important. With more attention going to recreational sailing the waiting times for marine traffic became more of an issue. Also, with trade offs being assessed on the entire life cycle span the movable bridges became less attractive from a cost perspective. In a number of cases the life cycle costs of aqueducts turn out to be close to the cost of moveable bridges and together with the uninterrupted road and marine traffic advantage the aqueduct was selected as the preferred option.

The report starts with an overview of aqueducts constructed in The Netherlands. To increase confidence and show the robustness of the solution itself some specific details with regard to waterproofing are given. By showing three different construction methods the versatility and applicability is demonstrated. At last a cost estimate of an aqueduct for the Margretheholm harbour is given.

1.2 Definition of the problem

A new temporary road for transportation of soil to a land reclamation in the Northern part of Copenhagen will be established. This road towards the land reclamation called Lynetteholmen will cross the current navigation channel to the Margretheholm harbour as shown in the figure below.

Figure 1.1 Location of the Lynetteholmen and the construction road

The developer of the land reclamation and their engineer proposed an embankment for the construction road and a bascule bridge so there will be access to the Margretheholm harbour. Unfortunately the bascule bridge has only limited opening hours.

1.3 Witteveen+Bos

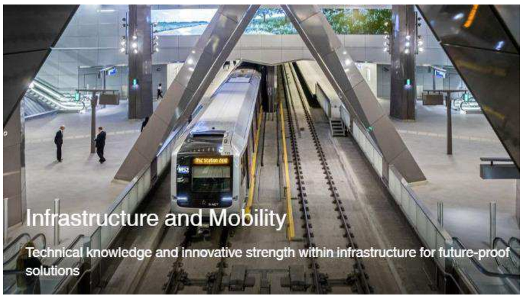
Witteveen+Bos is a firm of engineering consultants, established in the Netherlands 1946, with over 1,300 professionals across the Netherlands and 14 branch offices worldwide.

Around the world, both public- and private-sector clients call on Witteveen+Bos to help resolve the challenges they face. We provide advice to contractors, engineering and architectural firms, energy and water companies, railway and port authorities, and industry. In the public sector, we work for national governments, water boards, and provincial and local authorities. Our activities cover the entire chain, from policy-making and design to contracting and supervising construction. Witteveen+Bos aims to establish long-term relationships with her clients that enables us to meet their needs and expectations as effectively as possible while delivering maximum added value.

The many international projects that we have successfully completed over the years are evidence of our effective expertise and ability to adapt to local requirements. Witteveen+Bos has been involved in the design of the following aqueducts:
- Margaretha Zella aqueduct (Western ring road Leeuwarden) (paragraph 2.5.1).
- Richard Hageman aqueduct (Leeuwarden).
- M.C. Escher Akwaduct (Drachtsterweg, Leeuwarden).
- Hendrik Bulthuis aqueduct (Bergum).
- Geeuw aqueduct (Sneek) (paragraph 2.5.3).
- A4 Midden Delfland (paragraph 2.5.2).

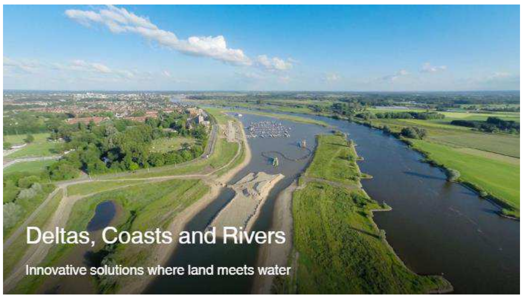
Currently Witteveen+Bos is involved in the following projects with similar civil structures:
- Maasdeltatunnel and Hollandtunnel (Rotterdam).
- the Scheldt tunnel (Antwerp).
- Fehmarnbelt tunnel (Denmark-Germany).
- ViaA15 roadway (deepened road way in between sheet-piles).

Infrastructure and Mobility



- Civil Structures for Railways
- Construction Management
- Infrastructural Engineering
- Smart Infra Systems
- Traffic and Roads
- Underground Infrastructure

Deltas, Coasts and Rivers



- Ecology
- Coasts, Rivers and Land
- Reclamation
- Flood Protection and Land Development
- Hydraulic and Geotechnical Engineering
- Ports and Waterways
- Water Management

The engineers of Witteveen+Bos worked on a lot of tunnels, viaducts and aqueducts in the Netherlands but also abroad. Three of these project (A4 Midden Delfland, Geeuwaquaduct and Haak om Leeuwarden) are highlighted in chapter 2.

2

PRACTICE OF AQUEDUCTS

2.1 Appearance

In the Netherlands aqueducts are quite common, especially in the northern part of the country. Due the number of waterways and lakes and the importance of sailing to the local tourism industry aqueducts are more and more selected in favor of movable bridges. From figure 2.1 the rapid increase in aqueducts in the last 10 years is shown.

Aqueducts are mainly constructed at the crossing of roads with canals and small rivers. Large river crossings are constructed with tunnels for which different techniques (other than aqueducts) are utilised. The main problem of the canals is not the professional shipping traffic but the recreational traffic. The fixed standing rigging (mast, or the tall upright post carrying the sails) of those ships would lead to exceptional high bridges or to an unacceptable amount of bridge openings.

Figure 2.1 Number of aqueducts constructed in The Netherlands

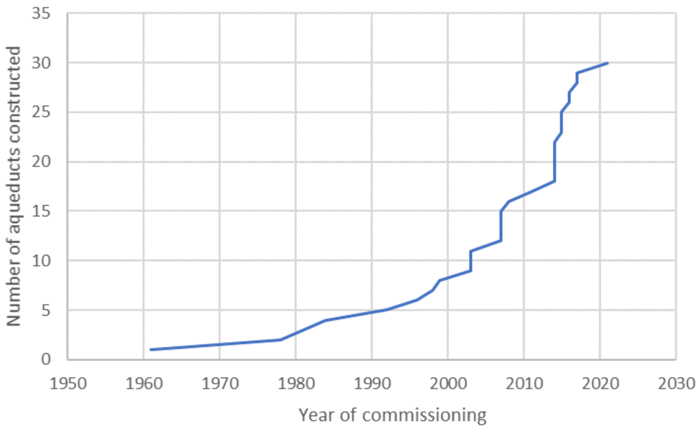


Table 2.1 shows a list with the 10 last build aqueducts. A few of these aqueducts are highlighted in the following paragraphs.

Table 2.1 Aqueducts constructed in the last 10 years

Name of the Aqueduct	Year of Execution
Dampoort aqueduct	2011
Amstel aqueduct	2014
Limesaquaduct	2014
Margaretha Zelle akwadukt*	2014
Richard Hageman akwadukt*	2014
Aqueduct Steenbergen aan Zee	2014
Eco-aquaduct Zweth en Slinksloot*	2015
Boxemtunnel	2015
Hendrik Bulthuis akwadukt*	2016
Aquaduct Vechtzicht	2016
M.C. Escherakwadukt	2017
Aquaduct Van Harinxmakanaal*	2017
Geeuwaquaduct*	2008

* projects Witteveen+Bos participated

Usually the ramps of aqueduct are less than 250 m and the closed section of the aqueducts rarely exceeds 50 m. This means that it is not classified as a tunnel and therefore no electrical and mechanical installations (i.e. ventilation) and emergency egress facilities are required. Needless to say is that a pump sump and lighting is required.

Aqueducts have been constructed in highways with 2x5 lanes and in local roads with 2x1 lane (and bidirectional traffic in one tube). The first aqueducts where constructed in highways in the densely populated western part of The Netherlands. Later on, smaller aqueducts with 2x1 lanes were constructed as well.

A rule of thumb used up to the nineties was that an aqueduct was around 3 times as expensive as an moveable bridge. Due to increased experience and optimalisations in construction methods a factor of 1.5 is now used.

Figure 2.2 Large (left) and small aqueduct (right)

2.2 Benefits of an aqueduct

There are a lot of benefits of building an aqueduct instead of a (movable) bridge, the most important benefits are summed up below:

- Road traffic is not disrupted (bridge will disrupt road traffic in opened position).
- Marine traffic is not disrupted (bridge will disrupt marine traffic is in a closed position).
  - Vertical clearance of vessels/ships/boats is infinite.
  - Vessels can sail in and out without waiting.
- No fendering works for waiting vessels required.
- No hydraulics needed for opening a bridge.
  - Reduces amount of maintenance.
  - No risk of malfunctioning.
- Low visual impact.
- Reduced noise impact.

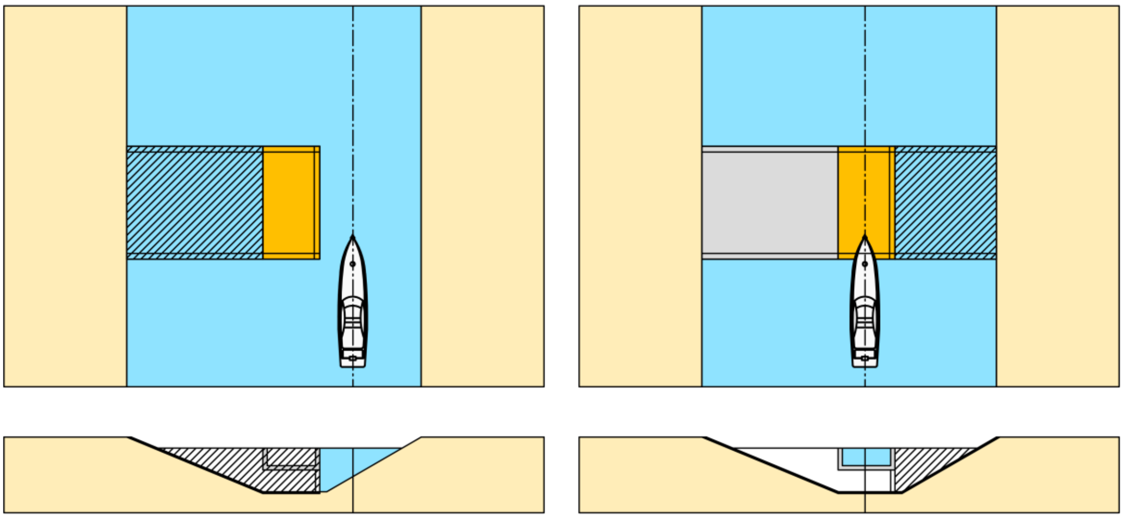
Disadvantages of aqueducts:

- Water safety. Flooding can occur when the ground level of the hinterland is lower than the water level. In the unlikely event of leakage of the aqueduct the hinterland will be flooded. A flood barrier or dike around the entrance will prevent floods in these circumstances.
- Construction cost. The initial investment (direct cost) of building an aqueduct is generally higher than the cost of building a bridge.

2.3 Phasing

For constructing an aqueduct there are two common methods. The first one is to construct the ramp and the aqueduct in two phases, for example first constructing the right side so vessels can use the other half. After finishing the ramp and the aqueduct the vessels can use the aqueduct and the left part can be build. This principle is shown in the image below. Minor dredging might be required to provided sufficient depth for the diverted temporary shipping lane.

Figure 2.3 Principle building an aqueduct in 2 phases



When it is not possible to divert the axis of the channel an aqueduct can be made by using an immersed tunnel. The tunnel element will be transported to the location and sunk in the channel. After the element is in place the vessels can cross the channel and the ramps can be built on either side.

Figure 2.1 Principle immersion technique for aqueducts

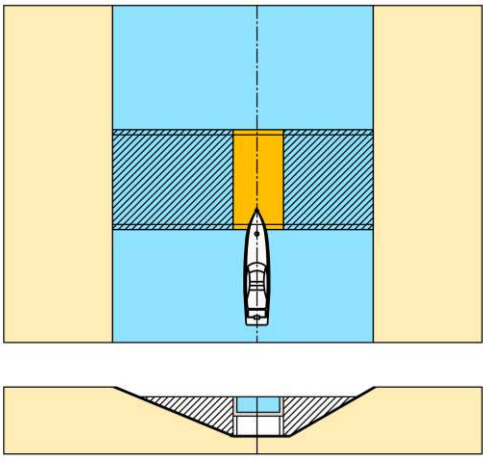


Figure 2.2 Immersed aqueduct in Harlingen

When the immersion technique is utilised the element is usually precast in one of the ramps. No access channel is required and the transport distance is limited. However, when construction time is important an aqueduct could be constructed elsewhere. This has however for aqueduct construction never been used.

2.4 Water sealing

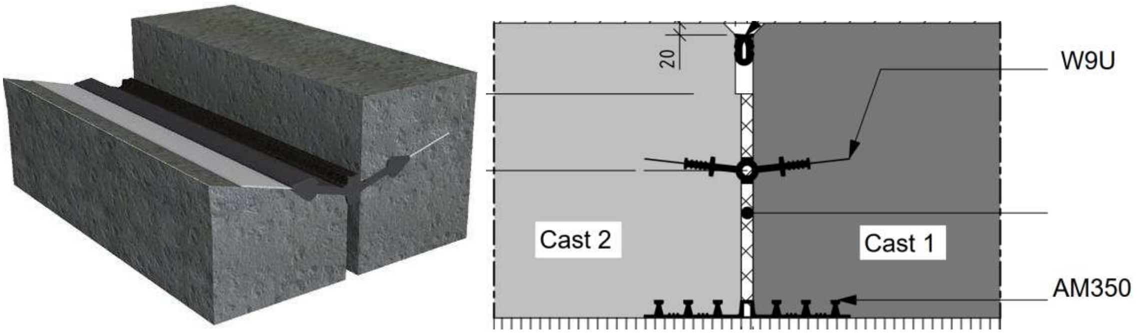
One of the most important issues in constructing an aqueduct is water tightness. Water tightness of the concrete or sheet piles is usually not a problem. Concrete itself is water tight when the usual detailing rules are applied. Sheet piles can leak through the joint but this can be solved by applying bituminous sealings in the joints or, in case that's not working, by welding the joints together. Attention has to be paid to the joint between the concrete segment, the joints between sheet piles and concrete and the joints between the aqueduct and the ramps. To assure a waterproof construction a couple of solutions can be used, the most common used solutions at tunnels and aqueducts are described below.

W9U-profile

When concrete structures are submitted to outside water pressures, in tunnels, cellars, off-shore reservoirs, etc., the joints between concrete sections are made watertight with water stops. For normal purposes standard rubber water stop with vulcanised steel strips alongside (type W9U) can be applied. This water stop will give water tightness between the concrete and the steel strips. However in practice, caused by shrinkages in the concrete and errors while pouring, in the area around the water stop the concrete can show fissures, gravel spots and the like. These issues can accommodate water seeping through the concrete. To prevent this leakage, a special type of water stop is developed type W9UI.

This type of water sealing is most used in underground structures of concrete. In tunnels and deepened road or train sections constructed from concrete these seals are used. This seal is also used in sealing the joint between a concrete part and a steel part. Therefore, the steel part of the W9U is welded to, for example, a sheet pile.

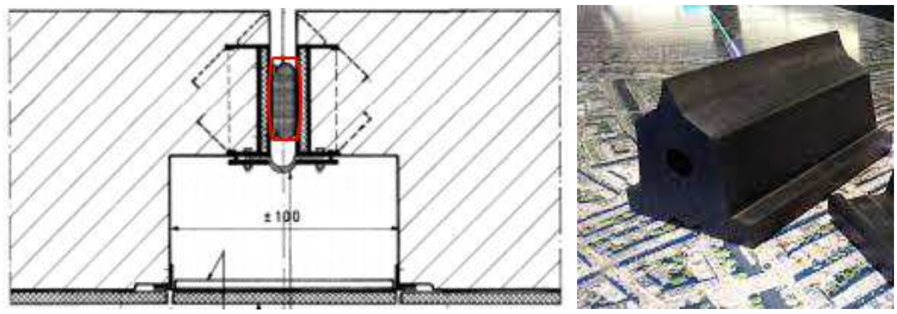
Figure 2.3 W9U profile in 3D view (left) and in cross-sectional view in structural slab (right)



GINA-profile

The Gina gasket and Omega seal can be used to make the water tight connection between the immersed aqueduct element and the ramps of the aqueduct. This combination of seals not only allows for sealing but also for the transfer of the hydrostatic loads and movements between the tunnel ends due to soil settlement, creep of concrete, temperature effects and if required earthquakes. The designs are generally based on the expected tunnel lifetime of 100 years. The GINA seal is used as a temporary water seal directly after immersion of an element. By the hydrostatic pressure the seal is compressed by itself. The omega-profile is the final water stop and is installed after immersion. In general the combination of GINA- and omega-seals is not used in aqueduct construction.

Figure 2.4 GINA-profile in immersed elements



Inflatable-seal

A more common method to water tight connect an immersed aqueduct to the ramps of the aqueduct is by making us of an inflatable seal. The rubber seal is installed on the embankment of the ramp and the first part of the aqueduct is immersed in between the embankment. After immersion the seal is inflated and a water tight connection is established. The connection is regarded as only temporarily. The final water stop is created by applying an omega seal over the joint. This methods has been successfully utilised in aqueduct construction.

Figure 2.5 Schematic sketch of inflatable seal (left)

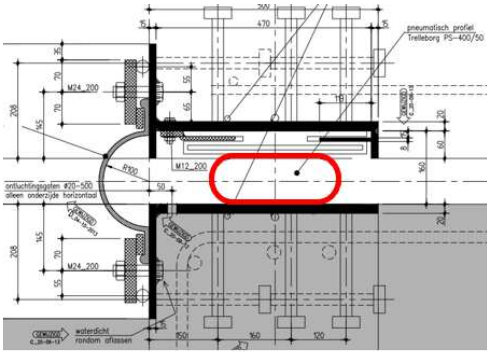
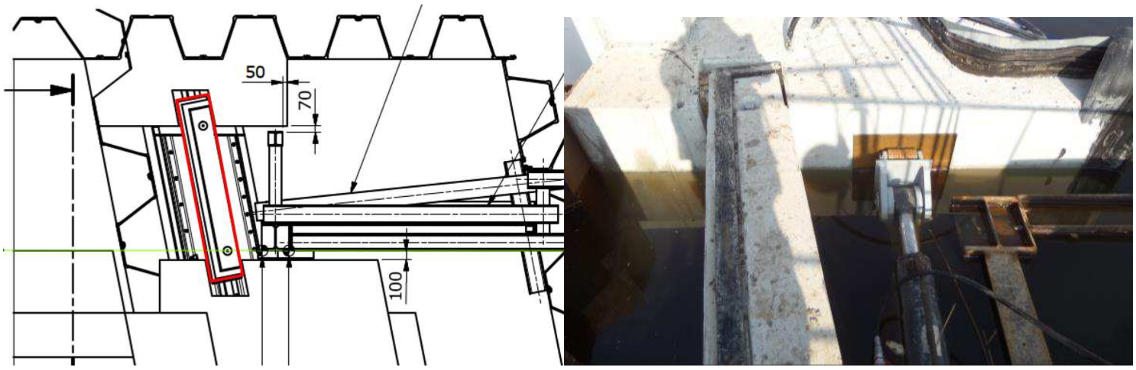


Figure 2.6 Inflated seal on construction site (right)

Stop log recess

A stop log recess can be used for closing the gap between a immersed tunnel and the cut-and-cover part (embankment of the ramp). A concrete slab surrounded by rubber profiles will be placed in pre-made recesses. This method guarantees the waterproofness between these elements.

Figure 2.7 Stop log recess



2.5 Highlighted Aqueducts

In this paragraph three aqueducts are shown which show the versatility of this kind of structure. Witteveen+Bos has been involved in the design and construction of all of these three aqueducts.

2.5.1 Project example Margaretha Zelle

The aqueduct Margaretha Zelle was part of the project Haak om Leeuwarden. This city in the north of the Netherlands was struggling with traffic jams almost daily. An additional road was made to connect two highways. This project contained a lot of viaducts, bridges and also an aqueduct. This aqueduct provides a crossing from the Johannes Brandsmaweg to the center of Leeuwarden over the Van Harinxmakanaal without traffic jams due to the opening of a bridge. As can be seen on the photo's below two lanes for cyclist have been included. The inclination for the cyclists has been reduced compared to the inclination for the road traffic by elevating the lane at the deepest section.

Table 2.2 Haak om Leeuwarden

General information

Overview	Location
	
Cliënt	Provincie Friesland
Country	the Netherlands
Location	Leeuwarden
Construction completed	2020
Construction type	Aqueduct
Google.Maps link	https://goo.gl/maps/A7EkpdCRw9Lu5yN39

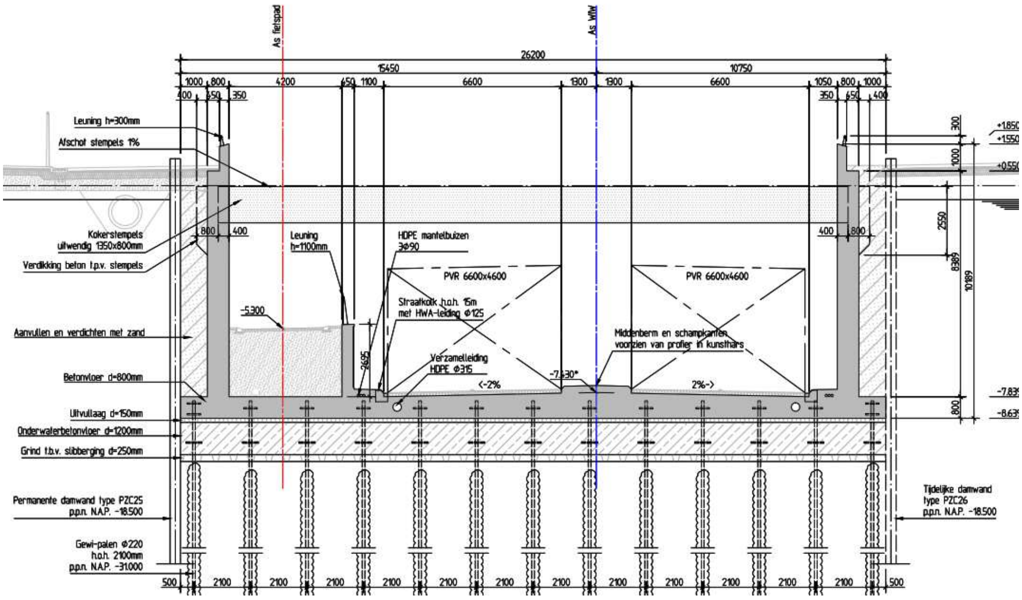
images/pictures: www.google.com/maps / own picture

Construction principle

To construct the aqueduct a sheet pile wall was placed and the ground was excavated. Afterwards an underwater concrete floor was cast and ground anchors were placed. After establishing a waterproof box, the reinforced concrete floors and walls where made. At the channel also a deck was constructed. The concrete floors and walls secure a waterproof tunnel in the user phase.

The sheet piles are only required temporarily to create a dry environment to built the final concrete structure. Also the underwater concrete is only required temporarily. For the Margretheholm harbour aqueduct the sheet piles can be used as final construction and no final concrete walls are required. It becomes more common to use the sheet piles also in the final phase and let them retain ground and water during the entire service life. In case aesthetically the sheet piles are unwanted concrete panels are placed in front of the sheet piles.

Figure 2.8 Cross-section of the open part of the aqueduct



2.5.2 Project example Eco-aquaduct Zweth en Slinksloot

The construction of the A4 Delft Schiedam motorway includes the construction of a 7-kilometer motorway that is built below ground level, a 2-kilometer long land tunnel, an aqueduct and a new connection to the Kethelplein traffic junction. The aim is to reduce the amount of traffic jams at the highway A13.

Table 2.3 A4 midden Delfland Eco-aquaduct Zweth en Slinksloot

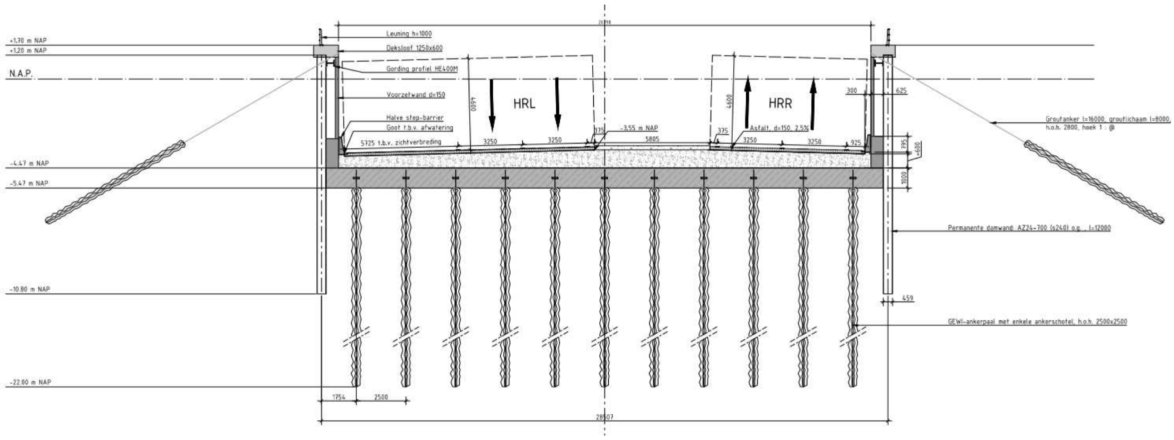
General information	
Overview 	Location 
Cliënt	Heijmans N.V.
Country	the Netherlands
Location	Schiedam
Construction completed	2015
Construction type	Eco- Aqueduct
Google.Maps link	https://goo.gl/maps/8XUYnxx9H7YAsZJx8
	images/pictures: www.google.com/maps

Construction principle

At the A4 project the sheet pile wall is not only used in the temporary situation but also in the user phase. Inside the dry construction pit (formed with sheet piles) a concrete floor is casted anchored with GEWI-anchors. In this design underwater concrete was not necessary. At the side of the road a cladding is placed against the sheet piles, this wall provides the fire safety.

Compared to the Margaretha Zelle aqueduct less material is used and therefore a cheaper construction is obtained. In this design a water tight connection between the structural floor with the sheet piles is required.

Figure 2.9 Section of the open part of the aqueduct



2.5.3 Project example Geeuwaquaduct

This aqueduct was part of a project to upgrade a regional road to a freeway nearby the city of Sneek in the province of Friesland. The existing drawbridge caused long waiting times for car traffic but also for the boats and ships. Due to five grade-separated viaducts and an aqueduct the traffic can cross the river Greeuw, a Railway and other roads without being disrupted.

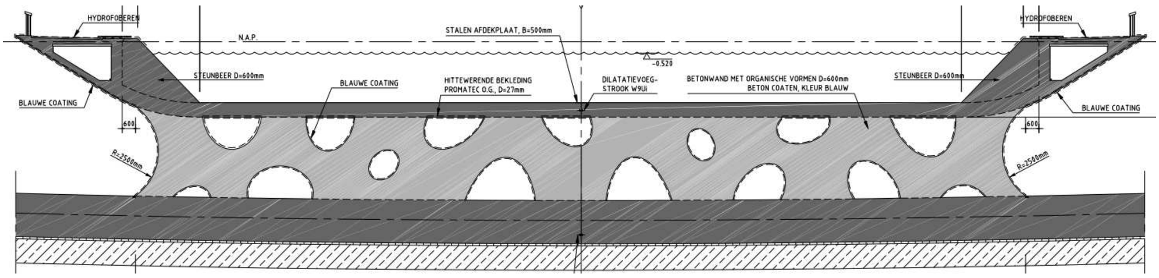
Table 2.4 Geeuwaquaduct

General information	
Overview 	Location 
Cliënt Country Location Construction completed Construction type Google.Maps link	Provincie Friesland. the Netherlands Sneek 2008 Aqueduct https://goo.gl/maps/75Yed4ZKAbW89J2R6
	images/pictures: www.google.com/maps / own picture

Construction principle

To construct this aqueduct the dry pit was made with two principles, one part with a sheet pile wall and the other part with a foil construction. After creating a dry pit the underwater concrete floor was cast and ground anchors where placed. After establishing a waterproof box, the reinforced concrete floors and walls where made. At the channel also a deck was constructed. The concrete floors and walls secure a waterproof tunnel in the user phase. The sheet piles where pulled after the concrete box was finished and could be uses somewhere else in the project.

Figure 2.10 section of the Aqueduct



3

AQUEDUCT FOR THE MARGRETHEHOLM HARBOUR

3.1 Introduction to the conceptual design

As an alternative to the proposal by By & Havn for a bascule bridge across the navigation channel to the Margretheholm Harbour, the Yacht Club Lynetten have prepared the present conceptual design for an aqueduct with ramps. The aqueduct and ramps have the same road alignment as proposed by By & Havn for the bascule bridge. The ramps down to the aqueduct have a slope of 6 % following maximum gradients according to regulation for Danish state roads. Witteveen+Bos was asked to review the design of the Yacht Club and propose potential improvements.

In the design of Yacht Club Lynetten a caission at the location of the fairway is included. A caisson shall only be used in case the fairway during construction cannot be diverted. In case of the Margretheholm harbour a temporary diversion of the fairway is possible and therefore a phased construction is preferred. Although the construction at the location of the fairway shall now be phased it is not believed that the total construction time – being approximately 1½ year from construction start - is affected.

A 3D-view of the construction principle including all mayor structural parts is given in the figures below.

Figure 3.1 Construction principle for aqueduct in Margretheholm harbour

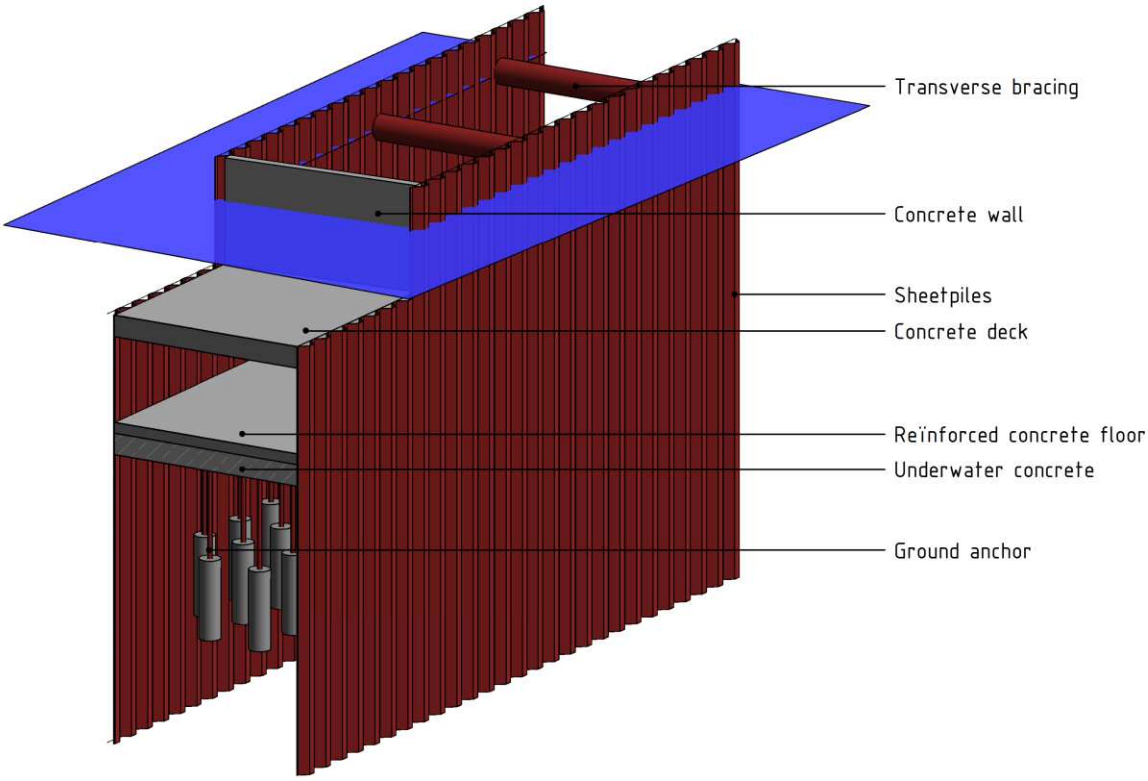
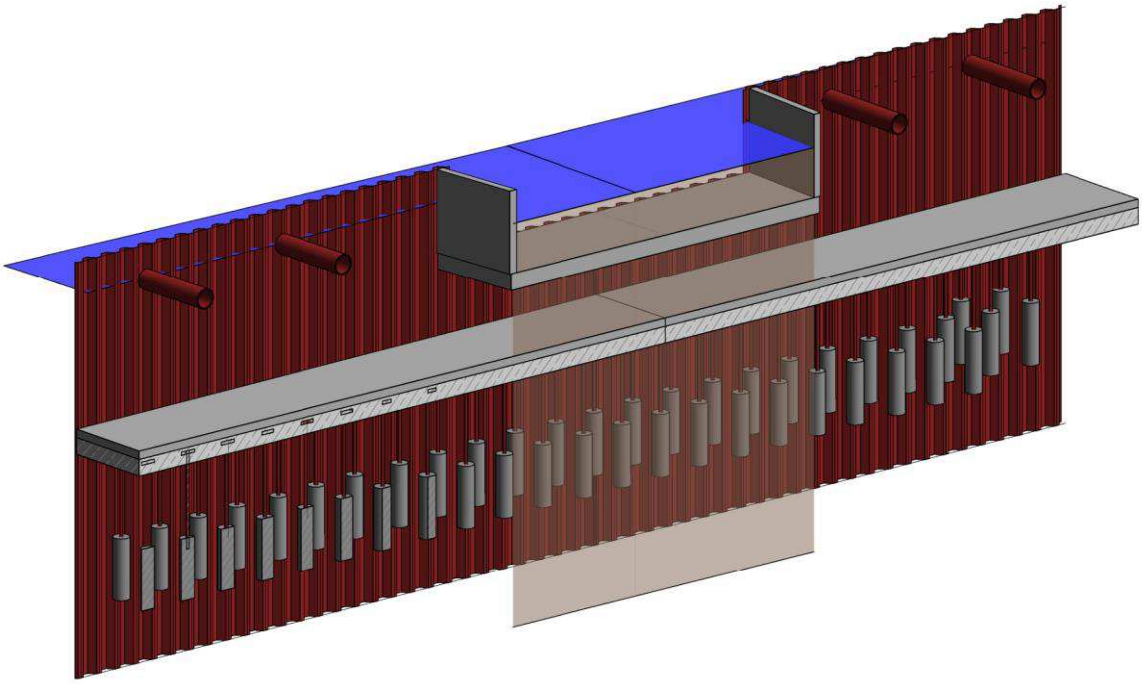


Figure 3.2 Construction principle for aqueduct in Margretheholm harbour (longitudinal section)



3.2 Construction principle

For the phasing of the construction it is assumed that the aqueduct is made in two phases as shown in paragraph 2.3. The ramps for the aqueduct are designed as a Cut-and-cover sections. First the sheet piles will be driven into the ground of the channel and the soil in between will be excavated. In the next phase the underwater concrete will be cast and the ground anchors will be places to prevent the floor from floating. To reduce materials and costs the underwater concrete is only placed at the lowest points of the underpass, at the higher points of the ramp only a reinforced concrete floor is required.

A reinforced floor will be made on top of the underwater concrete at the lower parts. The sheet piles, concrete floor will provide a waterproof box. In between the concrete floor and the sheet pile a rubber profile will ensure water tightness.

The sheet piles are provided with a fire-retardant coating, by applying this principle it is not needed to place a cladding. Without the cladding it is possible to reduce the width of the aqueduct, this will have a positive effect on the cost. The fire-retardant coating is also used at the Veluwemeer aqueduct in The Netherland as shown in figure 3.3.

Figure 3.3 Rire-retardant coating on sheet piles

3.3 Benefits

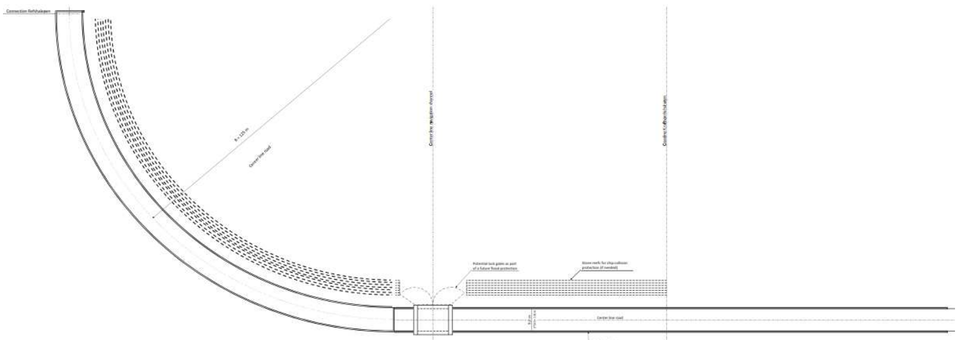
By choosing an aqueduct and not a movable bridge it would be possible to access the Margretheholm harbour for vessels and ships without limitation. Also the transport of soil to the Lynetteholmen will not be disrupted by the opening of a bridge. Due to a limited amount of hydraulic parts in an aqueduct in comparison to a bridge the risk of failing of the mechanism is reduced.

3.4 Disadvantage

Future use of the aqueduct

The current horizontal alignment and in particular the radius might pose a problem if it is decided to allow regular traffic in the future. The radius is quite narrow, so there is al possibility it would be a problem to see traffic in the other direction on time. A solution for this issue is to adjust the horizontal alignment into a straight alignment (possible since the aqueducts is not required to cross the fairway perpendicular).

Figure 3.4 Horizontal alignment



Due to the fact that the road will only be used as a construction road, barriers and other utilities would not be needed. By not applying barriers in the design the width of the aqueduct can be reduced to a minimum.

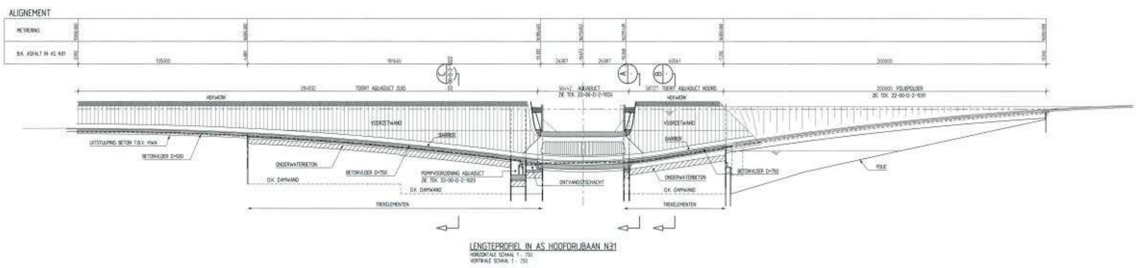
30 years instead of 100 years

When the cost are compared from a bridge and an aqueduct normally reduced maintenance is a big positive point for an aqueduct. In the lifespan of 100 years a lot of the movable parts of the bridge should be replaced so this is an expensive solution. Due to the fact that this is a temporary road this is not that big of an argument as it would have been if the construction was made for 100 years.

Comparison with Van Harinxma aqueduct

In the figure below the vertical alignment of the Harlingen aqueduct is shown. This aqueduct is wider than the aqueduct required for the Margretheholm harbour but is perfect to show the construction principle.
On the right side at a relative deep point the concrete box is transferred into an open excavation (with foil to avoid uplift). On the left side the concrete floor in between sheet piles continues into a deepened section with a length of 1.50 km.

Figure 3.5 Vertical alignment of Van Hanrinxma aqueduct in Harlingen



At the shallow section the underwater concrete is not present and only a final concrete slab is required. At the deep sections a final reinforced concrete slab is present on a temporary under water concrete slab.

Concrete panels in front of the steel sheet piles are used for aesthetic reasons. In the Margretheholm aqueduct the concrete panels can be omitted.

Figure 3.6 Cross-section of shallow sections of Van Harinxma aqueduct in Harlingen

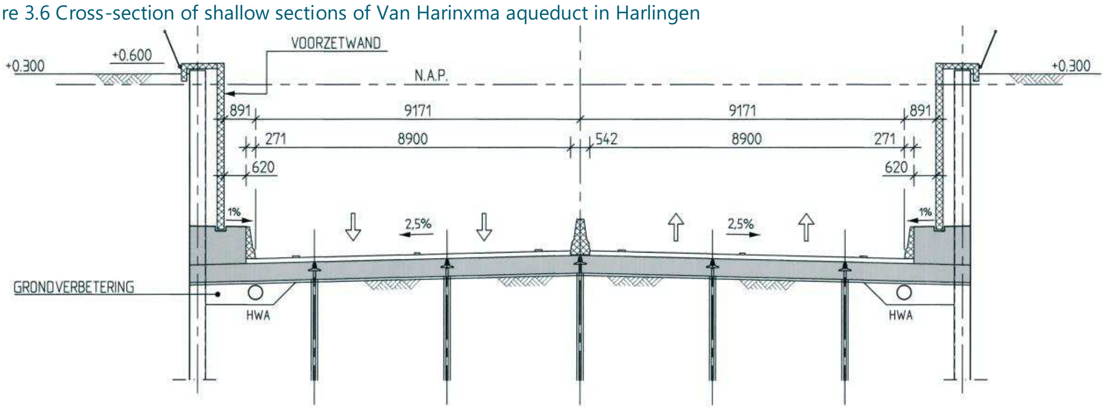


Figure 3.7 Cross-section of deep sections of Van Harinxma aqueduct in Harlingen

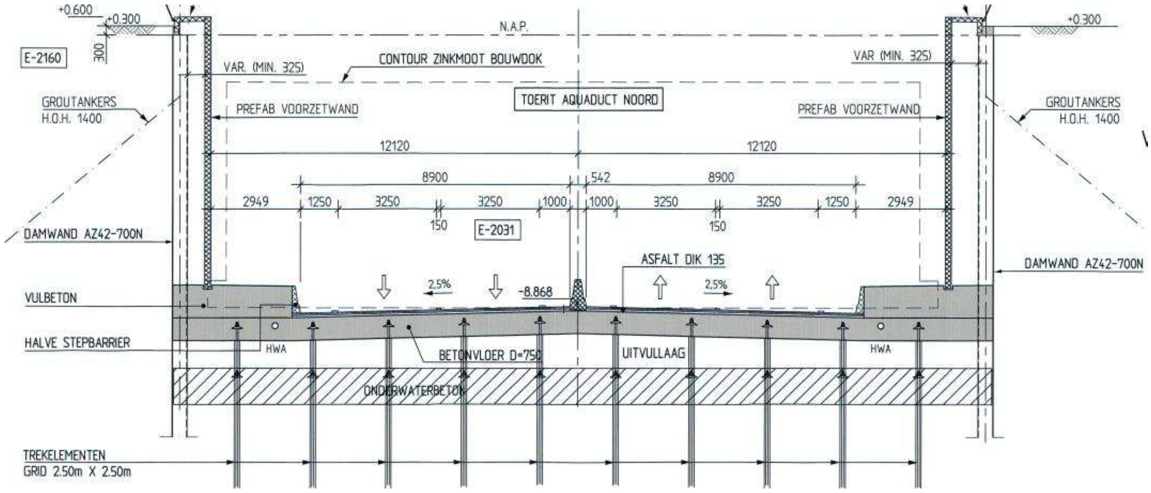


Figure 3.8 Photos of Van Harinxma aqueduct in Harlingen

4

COST ESTIMATION

Based on the main required dimensions for road and marine traffic an indicative sketch has been made to derive to main quantities. Structural dimensions (sheet pile weight, reinforcement rates, concrete thickness etc) have been estimated based on engineering judgement as no geotechnical nor structural calculations have been made.

An important difference with a regular aqueduct is the reduced design lifetime. This structure is designed for 30 years (instead of 100 years).

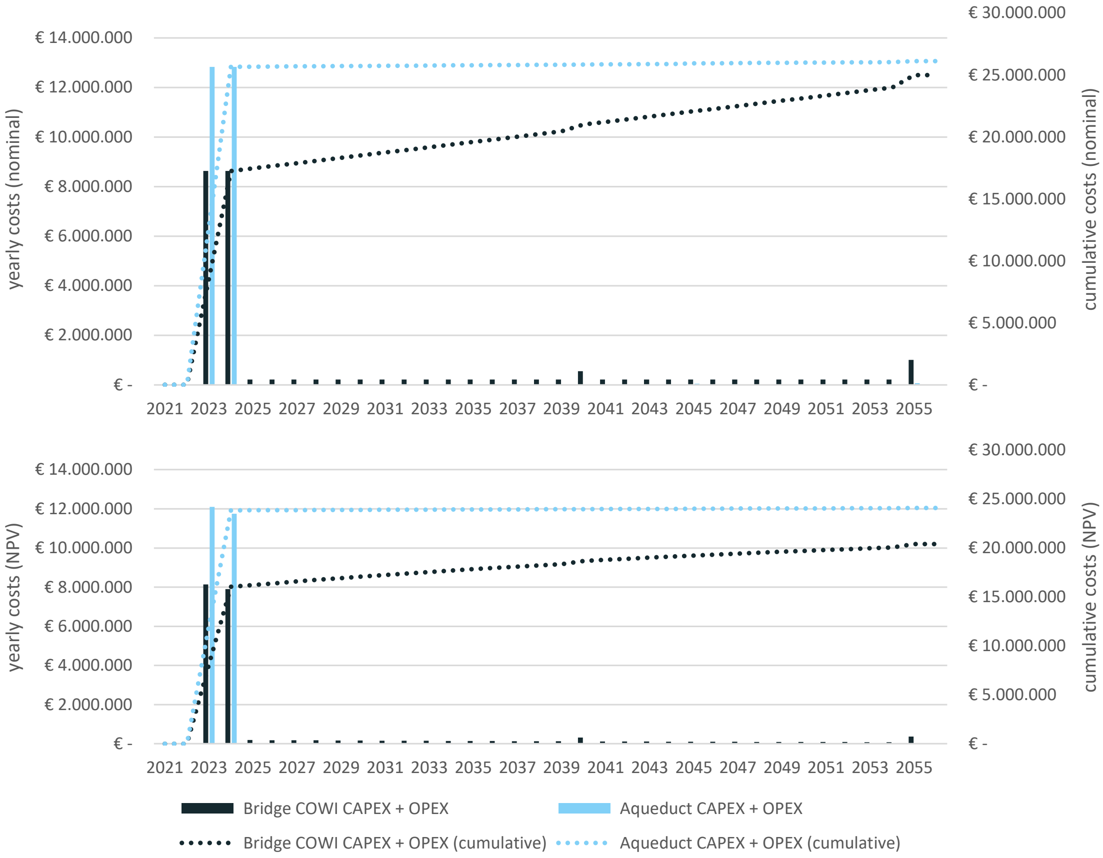
A second important difference with a regular aqueduct is the fact this road in only allowed to be used by construction traffic. In the design no future use by public traffic has been taken into account. The (rather steep) slope of 6 % and narrow road profile cannot be adjusted to meet future road design regulations after the construction period of 30 years.

With reference to appendix I we also believe the aqueduct is more expensive to construct than the simplified bascule bridge. However, despite the advantages for both road and marine traffic, we also believe the operational costs differ. An aqueduct has lower operational and maintenance cost and also lower costs of energy.

As shown in figure 4.1 the bars show higher initial costs for the aqueduct (capex) than the bascule bridge. Also the moveable bridge electrical component probably needs replacement within these 30 years. Mechanical installations are uncertain to last for 30 years. This also depends on the frequency of bridge openings we do not know. Yearly costs for both the bridge and aqueduct are hardly visible at this scale and level of detail. However as shown with the dotted lines, cumulative costs are slowly closing the gap. That means at a longer horizon the aqueduct might be cost efficient because of the lower re-investments (replacement) costs and lower operational expenditures.

In this cost comparison no costs for decommissioning has been taken into account. Both the bridge and aqueduct have large component and require specialised equipment in case of decommissioning. It is uncertain if the structure has to be removed or if life extension after 30 years is required. In case the life time of the crossing is extended to 50 or 100 years the aqueduct will become more cost efficient.

Figure 4.1 Capex and opex excluding VAT



For a more detailed description of all starting points and exclusions reference is made to the first page of appendix I. An overview of costs is given in table 4.1.

Table 4.1 Estimated cost

Item	Cost
Direct costs	12.475.231
Direct costs including allowance	14.346.515
Costs foreseen (including contractors overhead)	18.871.980
Construction costs (including contingencies)	22.646.376
Total investment costs	25.665.893

5

CONCLUSIONS

On a conceptual level the options of constructing an aqueduct in the Margretheholm harbour are evaluated. An underwater concrete slab in between two rows of sheet piles seems the best solution for constructing an aqueduct. On the underwater concrete a structural floor is cast. Both floors are connected with the sheet piles and anchored with GEWI-piles. As the fairway can be temporarily diverted no use needs to be made of a caisson.

Although this structure seems new for Denmark, the different parts utilised in the design have all been used in other projects in Denmark. Engineering firms, design institutes and contractors are familiar with the design of the parts although they have never used them together in aqueduct construction. Therefore, the overall risk of aqueduct construction is considered to be lower compared to moveable bridges were the electrical and hydraulic installations complicate design.

The construction costs of an aqueduct are higher than the construction costs of a movable bridge. However, due to the low operational cost and maintenance cost (compared to a moveable bridge) the total costs after 30 years are more or less similar.

At this conceptual level it cannot be concluded which construction is more cost efficient. What can be concluded is that an aqueduct shall be taken into account when comparing alternatives. With the additional benefits associated with an aqueduct this option shall be taken into account when making the trade off. A moveable bridge in front of a marine full of pleasure yachts seems, at least in The Netherlands, as an illogical solution.

Appendices

I

APPENDIX: COST ESTIMATE

PROJECT: AQUEDUCT REVIEW MARGRETHEHOLM HARBOUR
ESTIMATE CLASS: CLASS 5 CONCEPT SCREENING

Scope description and basis of estimate

Methodology and assumptions:
- Deterministic estimation of investment costs
- No technical drawings are available. Quantities are based on a sketch and the main required dimensions
- Private road (construction traffic only)
- Lifespan 30 years
- Road slopes allowed for 6 %

Risks:
- Risks are not quantified (probability x impact), no risk sessions are held. However, in the cost estimate a contingecy of 20 % is included to cover technical risks.
- No additional contingency is included for project related risks, like: legal, organisation, political or financial risks.

> The aim of this quick cost estimate is to compare alternatives. Differences are quantified for comparison purposes only.

Exclusions:

Construction costs
- Barriers, asphalt (not required)
- Soil or groundwater contamination (e.g. PFAS, asbestos etc.)
- Unexploded Ordnance (UXO)

Engineering
- Surveys (bathymetry, geotechnical, environmental)

Life cycle costs / OPEX
- Winter road maintenance (e.g. gritting rock salt)
- Decommissioning (end of life)
- Interests

Real estate
- Land plot acquisition
- Site clearance
- Claims due to urban planning decision

Remaining costs
- Relocate underground utilities (if any)
- Permitting
- Insurances (CAR)

Other (scope) exclusions
- Uncertainty reserve (e.g. P50 > P95)
- Reserve scope changes
- Costs most economical advantageous tender (MEAT)
- Financial costs
- Social costs/benefits (e.g. costs of waiting)
- VAT

Colofon

Project leader:	A.J.T. Luttikholt MSc
Project director:	R.P. Herrema MSc
Estimate standard:	CROW Publication137 (2010) www.crow.nl
Estimate model number:	W+B SSK-2010 Rekenmodel 3.05a (26-2-2020)

code	description	Direct cost Known	Direct cost Preliminaries	Indirect cost	Known cost	Contingency	Total
	INVESTMENT COSTS (by category)						
BK01	Construction costs Dike with movable bridge (estimated by Cowi)	€ -	€ -	€ -	€ -	€ -	€ -
BK02	Construction costs Aquaduct (by Sejlklubben)	€ -	€ -	€ -	€ -	€ -	€ -
BK03	Construction costs Aquaduct (W+B, quick&dirty)	€ 12.475.231	€ 1.871.285	€ 4.525.465	€ 18.871.980	€ 3.774.396	€ 22.646.376
BK04	Construction costs Aquaduct (by Sejlklubben) reviewed by W+B	€ -	€ -	€ -	€ -	€ -	€ -
BK	**TOTAL CONSTRUCTION COSTS**	**€ 12.475.231**	**€ 1.871.285**	**€ 4.525.465**	**€ 18.871.980**	**€ 3.774.396**	**€ 22.646.376**
VK	**TOTAL REAL ESTATE**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
EK	**TOTAL ENGINEERING**	**€ 3.019.517**	**€ -**	**€ -**	**€ 3.019.517**	**€ -**	**€ 3.019.517**
OBK	**TOTAL REMAINING COSTS**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
INV	**SUBTOTAL INVESTMENT COSTS**	**€ 15.494.748**	**€ 1.871.285**	**€ 4.525.465**	**€ 21.891.497**	**€ 3.774.396**	**€ 25.665.893**
OORINV	Project related contingencies					€ -	€ -
	INVESTMENT COSTS DETERMINISTIC	**€ 15.494.748**	**€ 1.871.285**	**€ 4.525.465**	**€ 21.891.497**	**€ 3.774.396**	**€ 25.665.893**
SINV	Skewness					€ -	€ -
	INVESTMENT COSTS PROBABILISTIC (Mu-value)				**€ 21.891.497**	**€ 3.774.396**	**€ 25.665.893**
BTW	VAT	excluding			€ -	€ -	€ -
	INVESTMENT COSTS EXCLUDING VAT				**€ 21.891.497**	**€ 3.774.396**	**€ 25.665.893**
	Bandwidth: with 70% certainty investment costs excluding taxes lie between				*M€ 15,4*	*and*	*M€ 35,9*
	Variation coëfficiënt (estimated)					*40%*	
	Risks in relation to known costs					*17%*	

Client:	Copenhagen Yacht Club	Price level:	2021	Date:	18-5-2021
Project:	Aqueduct review Margretheholm Harbour	Version:	01	Project code:	126592
Sub-item:	Aquaduct (W+B, quick&dirty)	Status:	Final	Author:	SCHE4

code	description	quantity	unit		unit rate		total
3							
	INVESTMENT COSTS						
40	**Substructure**						
400310	*Aquaduct*	-		€	-	€	-
400320	Supply and install permanent sheet piles 136 kg/m²	4.080,00	m²	€	400,00	€	1.632.000,00
400330	Supply and install permanent sheet piles 136 kg/m²	6.800,00	m²	€	400,00	€	2.720.000,00
400340	Supply and install permanent sheet piles 169 kg/m²	3.400,00	m²	€	425,00	€	1.445.000,00
400350	Fire resistant coating	5.929,31	m²	€	75,00	€	444.698,10
400360	Temporary sheet piles 150 kg/m²	3.400,00	m²	€	310,00	€	1.054.000,00
400370	Supply and install girders	428,00	m	€	250,00	€	107.000,00
400380	Supply and install steel struts	35,00	pcs	€	10.000,00	€	349.999,84
400390	Supply and install GEWI-anchors, length 24 m	120,00	pcs	€	3.200,00	€	384.000,00
400400	Supply and install GEWI-anchors, length 26 m	114,00	pcs	€	3.500,00	€	399.000,00
400410	Supply and install tremie slab, thickness 1 m	3.925,90	m³	€	125,00	€	490.737,50
	Total Substructure			**€**	**9.026.435,44**		
50	**Earth works**						
500310	*Aquaduct and ramps*	-		€	-	€	-
500320	Excavate from building pit	1.608,20	m³	€	5,00	€	8.041,00
500330	Excavate from building pit ramps	20.244,40	m³	€	5,00	€	101.222,00
500340	Transportation and placement soil surplus (in nearby reclamation)	21.852,60	m³	€	7,50	€	163.894,50
500350	Dredge and dispose from access channel	4.000,00	m³	€	10,00	€	40.000,00
	Total Earth works			**€**	**313.157,50**		
60	**Concrete works**						
600310	In situ concrete base slab between sheet pile walls (175 kg/m³)	3.367,76	m³	€	385,00	€	1.296.587,60
600320	In situ concrete capping beam (100 kg/m³)	996,00	m³	€	525,00	€	522.900,00
600330	In situ concrete elevated slab aquaduct (200 kg/m³)	241,23	m³	€	610,00	€	147.150,30
600340	In situ concrete exterior walls aquaduct (200 kg/m³)	170,00	m³	€	700,00	€	119.000,00
600360	Dewatering cellar	50.000,00	EUR	€	1,00	€	50.000,00
	Total Concrete works			**€**	**2.135.637,90**		
70	**Misc**						
700310	Mechanical and electrical installations pump cellar	1,00	EUR	€	100.000,00	€	100.000,00
700320	Vessel guiding structures and beacons	120,00	m	€	7.500,00	€	900.000,00
	Total Misc			**€**	**1.000.000,00**		
	Direct costs					**€**	**12.475.231**
NTD031	Additional items	15,0%		€	12.475.231	€	1.871.285
	Direct costs incl. allowance					**€**	**14.346.515**
IK036	Non-reoccurring costs (e.g. mob/demob)	2,0%		€	14.346.515	€	286.930
IK037	Site facilities	2,0%		€	14.346.515	€	286.930
IK038	Management (by building contractor)	2,0%		€	14.346.515	€	286.930
IK039	Site organisation (eg. foreman, site managers)	10,0%		€	14.346.515	€	1.434.652
IK0310	General costs	8,0%		€	16.641.958	€	1.331.357

Client:	Copenhagen Yacht Club	Price level:	2021	Date:	18-5-2021
Project:	Aqueduct review Margretheholm Harbour	Version:	01	Project code:	126592
Sub-item:	Aquaduct (W+B, quick&dirty)	Status:	Final	Author:	SCHE4

code	description	quantity	unit	unit rate		total
3						
IK0311	Profit	3,0%	€	17.973.315	€	539.199
IK0312	Risk	2,0%	€	17.973.315	€	359.466
	Indirect costs ('contractors overhead')	32%			**€**	**4.525.465**
VZBK	**Costs foreseen**				**€**	**18.871.980**
RBK033	Contingency	20,0%	€	18.871.980	€	3.774.396
RBK	**Contingencies**	20%			**€**	**3.774.396**
BK03	**Construction costs Aquaduct (W+B, quick&dirty)**				**€**	**22.646.376**
VK03	**Real estate Aquaduct (W+B, quick&dirty)**				**€**	**-**
EK031	Detailed engineering contractor	4,0%	€	18.871.980	€	754.879
EK032	Engineering consultancies (design)	4,0%	€	18.871.980	€	754.879
EK033	Client's organisation (tendering, permitting)	4,0%	€	18.871.980	€	754.879
EK034	Site supervision, site management	4,0%	€	18.871.980	€	754.879
EK03	**Engineering Aquaduct (W+B, quick&dirty)**	16%			**€**	**3.019.517**
OK031	Permits, insurances	0,0%	€	18.871.980	€	-
OK033	Taxes, import duties etc	0,0%	€	18.871.980	€	-
OBK03	**Remaining costs Aquaduct (W+B, quick&dirty)**	0%			**€**	**-**
INV03	**Total investment costs Aquaduct (W+B, quick&dirty)**				**€**	**25.665.893**