

Koos Spelt

Geotubes as the Core of Guide Dams for Naviduct at Enkhuizen, The Netherlands

Abstract

Geotubes are being used in the construction of guide dams for the Naviduct at Enkhuizen in The Netherlands. These sausage-shaped sacks are made from geotextiles that are hydraulically filled with sand. They form the core of the dams and are then covered over with a layer of quarry stone. The system, developed by a Dutch company, was first used in the United States as a coastal defence. Compacting the sand into these geotubes enables the use of locally occurring sand that would otherwise be too fine. This makes a considerable contribution to sustainable construction work and constitutes a step forward in the use of innovative techniques in hydraulic engineering.

Introduction

The Krabbersgat Lock at Enkhuizen is an important bottleneck in the main network of waterways in The Netherlands. Owing to the increase in recreational shipping, waiting times at the locks can reach up to 3 hours in the peak season. Since the bridge needs to be raised for most vessels, long waiting times ensue for road traffic also. In the future, traffic on both water and road is expected to become even busier.

In order to deal with this bottleneck, the Department of Public Works for the IJsselmeer area has developed three solutions:

- the construction of an additional lock chamber alongside the existing Krabbersgat Lock;
- an aqueduct with a resistance channel on either side and with an underpass for traffic;
- the construction known as a “Naviduct”.

The last, the Naviduct, is a combination between an aqueduct and a lock whereby road traffic is diverted under the lock chamber via a tunnel. The Naviduct seemed to be the most favourable solution because

After receiving his degree in civil engineering at the Technical University in Arnhem, Koos Spelt started at Baggermij Boskalis b.v., becoming chief surveyor and superintendent on several sandfill and dry-earth moving jobs near Rotterdam. He has worked in Nigeria (Port Harcourt), in Singapore, and was project manager in Kota Bahru, Malaysia. In 1992 he became project manager on several riverbed protection projects in Germany. In 1994 he was project manager on a pilot project to do environmental dredging with backhoes within 10 cm accuracy to clean up sand out of polluted sludge, using new dredging techniques with the environmental dredger *Vecht* on the highly polluted Ketelmeer. At the moment he is project manager on the Naviduct project in Enkhuizen, The Netherlands.



Koos Spelt

the lock capacity was tripled as a result of it and traffic obstruction was reduced to a minimum. The new lock has two lock chambers while the former lock also remains in use for vessels that can pass beneath the bridge. The difference in height from the dike to the Naviduct is 17 metres for road traffic and approximately 15 metres for cyclists. The construction of the Naviduct makes soil available that can be used both for the construction of the guide dams and for the construction of peninsulas. These protect the Naviduct from drifting ice and are laid out as pre-shore zones with conservation areas.

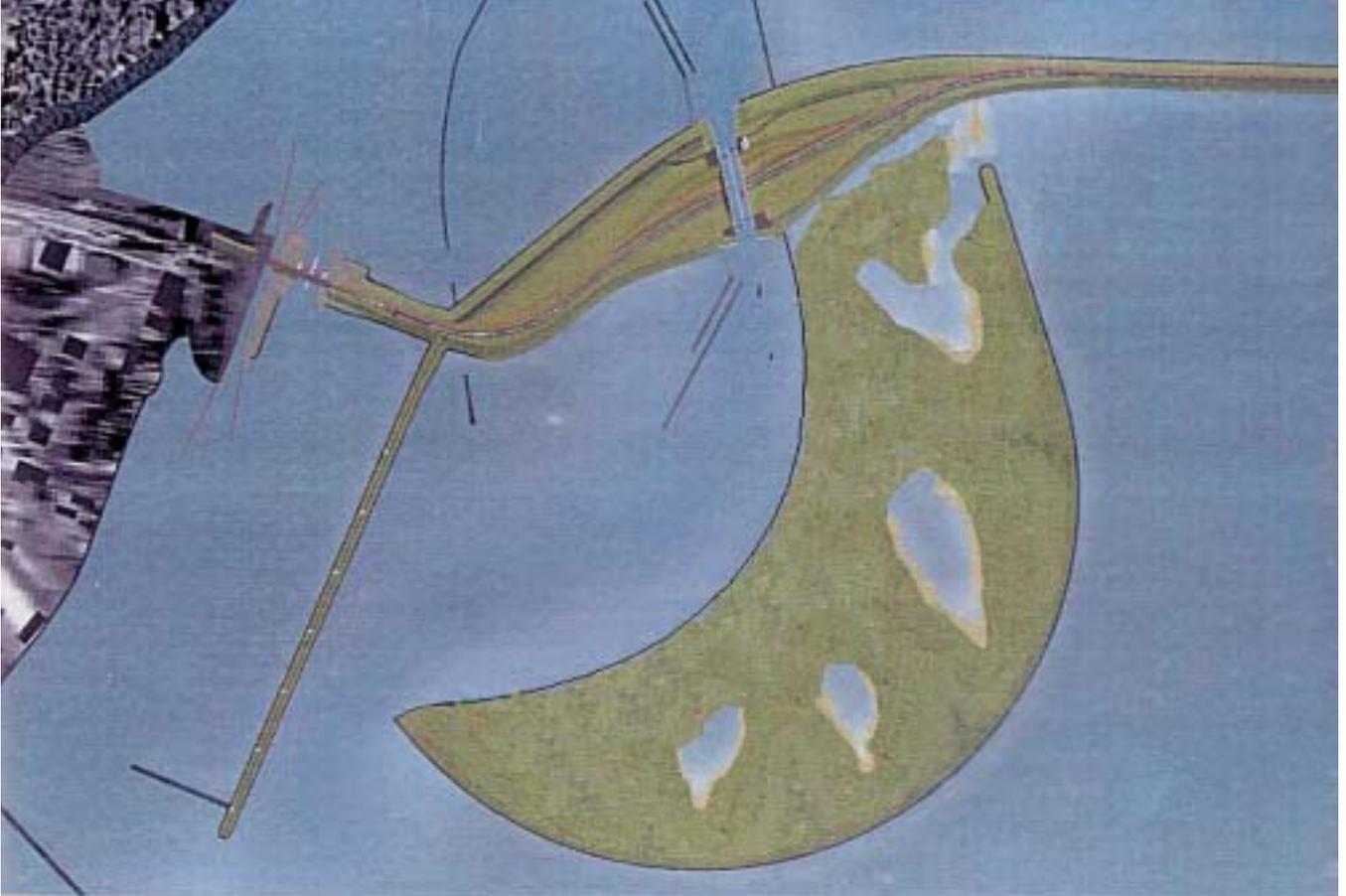


Figure 1. Helicopter view of the Enkhuizen Naviduct with the pre-shore areas:
The geotubes are worked into the dams.

SUSTAINABLE CONSTRUCTION WORK AND INNOVATION

In designing the Naviduct (Figure 1), attempts have been made to make use as much as possible of the materials that are released. This contributes towards the principles of "sustainable construction work" as it lessens the need to transport building materials from elsewhere, and also provides savings in construction costs. The sand on site is not suitable for the raising of the guide dams, because it is of uniform grain size and too fine to withstand the wash of the Markermeer. For this reason, it was decided to use geosystems so that the sand, which becomes available can be utilised, even though it is too fine.

There is limited experience in The Netherlands in using these techniques. Experience has been gained in various projects using submerged components, such as geocontainers and relatively small "sand sausages". Tests were also carried out on an experimental scale in the 1980s on filling some "sand sausages". However, various large-scale projects have been carried out in the United States and the Far East.

For the Naviduct, the geotubes or "sand sausages" (cylindrically shaped geotextile bags) are filled with sand and are later covered with a surface layer of quarry stone. The materials resulting from the excavation of the lock chambers and the navigation access channels are used in the peninsulas, according to the principle of making local use of material. Class 2 material is placed on the bed and is covered with class 0 material.

PREPARATION

The work was contracted out on 15 May 1998. Following negotiations, the Krabbersgat Lock Combination Naviduct ("Combinatie Naviduct Krabbersgatsluis", CNK, was selected from thirteen tenderers). This combination makes use of the years of experience in geosystems of the subcontractor Van den Herik in Sliedrecht, as well as being the offer with the best price-quality ratio (Table I).

An extensive preparatory investigation was carried out by CNK, in the summer of 1999 because of the scale of the work and the innovative character of employing geosystems on this scale. As well as materials research, practice tests were undertaken on filling sand-sausage prototypes. It appeared from these that changes to the shape of the filling holes and the hydraulic properties of the geotextile were necessary. The geotextile became clogged as a result of congestion and natural filtrate build-up, bringing the filling of the sand sausage to a standstill. Instead of the prescribed pore size (O90) of 100 µm, a geotextile was used with an O90 of 250 µm. Experiments were also carried out using different types of stitched seams to make reliable joins.

FRAMEWORK

A geotube or sand sausage is made from woven geotextiles. These are produced on looms in widths of 5 m to 5.20 m. The properties depend on the type of mater-

Table I. Project data.

Project	Construction of the Enkhuizen Naviduct
Client Management	: Department of Public Works of the IJsselmeer area : Construction Service of the Department of Public Works
Client composed of	: Krabbersgat Naviduct Combination ("Combinatie Naviduct Krabbersgat") : VBK Hoorn bv, Van Laere nv (B) and Boskalis bv.
Start	: 1 April 1999
Completion	: 1 April 2003

ial (usually Polypropene (PP), or Polyethene (PE) or Polyester (PET)), the type of thread and the weaving technique used. The geotube is made up of ring-shaped pieces with a standard width of 5.20 m. The length depends on the required diameter of the geotube. The weft edges (production width) of the rings are sewn together. The geotube's continuous seam must lie on the bottom. The pressure of the sand decreases the tensile stress on the seam. Fastening loops are attached to the tubes of the Naviduct every five metres so that the Naviduct tubes can be attached to the steel tubes.

Flexible, cylindrical filling hoses are attached to the top of the tube, with oval connectors for the correct distribution of the forces. The filling holes are fixed in a straight line on the top of the tube to prevent the tube from rolling during filling. The end of the tube is stitched up to close it. The first filling hole is at 7.5 m

from the end of the tube. The geotextile properties depend on the sand used. As a rule of thumb $O_{90} = 2 \times D_{50}$ of the sand. For sand sausages with a diameter of 3.92 m (circumference 12.30 m) and 105 m long, the geotextile's tensile strength must be 100 kN/m.

EXECUTION

Soil mechanics research was carried out in the preparatory phase. Seabed protection was incorporated subsequently. A new installation technique was employed instead of using traditional Dutch mattresses (Figures 2 and 3).

This technique involves the geotextile being put in place from a special pontoon using a roller system. The location is closely monitored to an accuracy of 10 cm using the Digital Global Position System (DGPS).

Figure 2. The geotubes made of geotextiles are filled with a water-sand mixture.





Figure 3. The connection point of the filling pipe and the geotube.

During positioning, the 15 m wide geotextile is kept firmly on the bed by mechanical means using a pressure roller. Two crane ships sailing along together place a 10-60 kg layer of quarry stone on either side of the geotextile. Approximately 4000 m² of seabed protection is put in place daily in this way.

The pre-assembled folded packages have a length of 105 metres. No overlapping is necessary because the pieces of geotextile are sewn together on the pontoon.

To fix the geotubes, steel tubes are pushed into the soil in the longitudinal axis of the soil protection 5 metres apart. The geotubes are attached on the left and right to the steel tube using specially affixed loops. A settlement beacon is positioned every 105 metres to allow settlement of the subsoil to be monitored. The geotubes have a length of 105 m and diameter of 3.92 m. The filling holes are placed at intervals of 15 m. Filling is done using a light water-sand mixture of 2-5%.

When the geotube is under pressure the concentration is increased to 15%. The sand sausage is filled first to approximately 80 to 90% from one side and then from the other end. A number of filling holes are open during filling and the filling tube has a pressure relief valve to prevent pressure in the geotube from becoming too great and causing damage. A relatively open geotextile has been used for the geotubes in order to

limit residual settlement. As a result of this, the finest fraction is washed away during filling to an extent of approximately 20%.

A geotextile is placed over the geotubes to give them additional protection from damage and UV radiation. A "catamaran" has been developed for this, consisting of two flat-bottomed barges joined together.

An unrolling mechanism is in place on top of this with which the geotextile is pulled over the geotubes. Immediately behind this, the geotextile is covered with quarry stone (gradation 10-60 kg) originating from Belgium. In the second phase, after settlement, the dam is given a final load of quarry stone (40-200 kg) originating from Belgium and Germany. Between 20 and 25 tonnes of quarry stone is used per running metre of guide dam (Table II).

BY-PRODUCT RECLAMATION WORK

The material brought up from the trench and the access channels is sprayed into the pre-shore areas. In doing this, the contractor has laid out this area with a great degree of freedom. Experience was gained in the construction of pre-shore areas during the construction of the Ketelmeer depot. A temporary partition dam has been raised to enable work to progress quickly.

Table II. Material type, quantities, properties and origin.

Material	Quantity	Properties	Origin
Sand/peat	900,000 m ³		Houtribdijk
Geotextile (bed protection)	79,000 m ²	Tensile strength Sand density Porosity	80 kN/m 250 µm 25 ltr/m ² /s Amoco Fabrics, Gronau (G)
Geotextile (geotubes)	93,000 m ²	Tensile strength Sand density Porosity	100 kN/m 200µm 15 ltr/m ² /s Ten Cate Nicolon Almelo
Geotextile (sand-sausage protection)	60,253 m ²	Tensile strength Sand density Porosity	80 kN/m 250µm 25 ltr/m ² /s Amoco Fabrics Gronau (G)
Quarry stone 10-60 kg Bed protection + protection of the sand sausages	18,000 tonnes	Density 2,650 kg/m ³	Sprimont, Gralex, Cimescaut (B)
Quarry stone 40-200 kg Surface layer for guide dams	74,000 tonnes	Density 2,650 kg/m ³ Density 2,700 kg/m ³	Cimescaut, Sprimont, Dulière, Marche le Dames (B) Ochtendung (G)

Furthermore, the area has been artistically laid out, with flowing height variations and a series of artificial inlets. It is important that stagnant water does not occur and that the pools are connected to the water from the Markermeer. It is expected that seeds brought in by the water and the wind will germinate in the course of the summer and that the first pioneer vegetation will be visible at the end of summer.

Conclusions: Experience and Future Possibilities

From the experience gained from installing geotubes for the Naviduct, it would appear that these systems could be put to good use in The Netherlands. As so often happens with innovative techniques, experience was gained that had not been predicted in studies or in earlier projects. A geotube was filled on the construction site by way of a test to obtain a clear insight into the filling process of the geotubes. Behaviour will be researched and reported on the basis of video footage and an extensive measurements programme.

The construction process is less manageable, particularly in shallow water with large fetches. This has been solved in the Enkhuizen project by working in the lee of the floating equipment and by constructing the outermost dam first. The results were that the waves were

subdued, enabling the innermost dam to be constructed under good conditions as well.

Since experience has been acquired in other projects on the construction of geotubes with much larger dimensions, this technique has perspectives to offer for future hydraulic engineering projects in The Netherlands. Working on the seabed in deep water can be made possible, irrespective of the weather conditions, through the development of special equipment and the construction of structures using geotubes. Furthermore, research into manufacturing techniques for continuous geotubes with greater dimensions may increase the efficiency and usability of these systems in large-scale (coastal) hydraulic engineering projects.