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BENEFICIAL USE OF DREDGED SEDIMENTS USING GEOTEXTILE TUBE TECHNOLOGY

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Abstract. In the Netherlands, over the last 10 years, some very interesting projects have been executed, all based on the idea to use dredged sediments in order to save on construction materials and, by doing so, on project cost. On a much larger scale in different parts of the world the same working principles have enabled some major projects to see the light. This paper will showcase some of the works that were done and discuss which lessons have been learned. It will give an overview of a variety of applications, discussing some of the earlier works like the small revetments in inland waterways (Kampen), riverbank restoration (Zutphen), and dike strengthening (Dubbele Wiericke), to continue highlighting two bigger projects, one in China (Tianjin EcoCity) and another in Brazil (Embraport, Container Port Santos) where dredged sediments were used to form new platforms in open waters.

Keywords: Geotextile tubes, Geotextile containers, contamination, dredging, sediments re-use, sludge, remediation, Geotube®, Carbon Footprint.

1. Introduction

TenCate is the leading manufacturer of Geotextile tube technology starting with sand filled tubes for cores of dikes and dams, revetments, etc. In the final decades of the twentieth century the technology of filling specially designed tubes with flocculated sludge was developed for containment and dewatering. This technology is nowadays well known for dewatering of marine silts, sludge's, sediments, lagoon clean outs, industry, pulp and paper, mining etc. In general; where sludge is a problem, geotextile tubes can be a valuable, very cost effective solution. 10 years ago the first ideas were explored to use TenCate Geotube® containers filled with flocculated silts, as new "building blocks", within the same project. To get this idea accepted is not always easy as sludge is not seen as a building material but as waste which has to be removed. The projects executed over the last years have proven that dredged sediments in combination with geotextile tube technology can be a valuable option to save on new construction materials. This paper will give an overview of projects starting with the first steps to major projects where dredged material were re-used in the foundations of new areas.

2. Project Kampen

One of the earliest projects where this new technology was used was a project in Kampen, the Netherlands. Here a semi-submerged, geotechnical structure (Fig 1.) was made using flocculated silts. The material was not contaminated and came from the same waterway. The working method is simple. The eroded berm is first prepared to give the tube a proper base. Poles are installed to fix the tubes and to prevent them from rolling in towards the centre of the waterway. The tubes

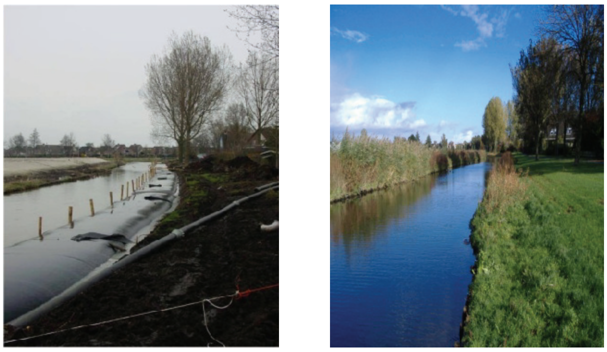

Fig 1. Project Kampen executed and one year after completion of the project

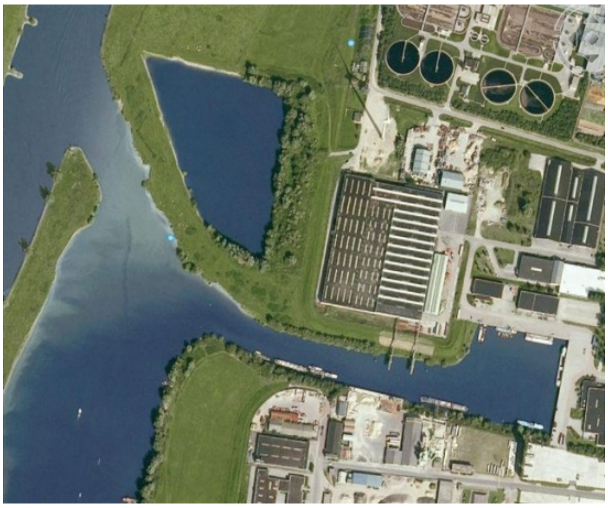

Fig 2. Harbour entrance and river Ijssel

Fig 3. Covering tubes after consolidation of the infill

are then filled in the usual way. After several refills and sufficient consolidation the filling proces is stopped and the tubes are covered with earth. Grass is seeded and by the end of a year the new bank protection is effective and green, not showing anything of the structure below. Spontaneously or planned, reeds may develop on top and through the structure of the geotextile tube. This method saves the cost of new construction material and obviates disposal cost.

3. Project Zutphen

The city of Zutphen in the Netherlands is located on a tributary of the Rhine, the river IJssel. The old harbour was being refurbished as part of a restoration plan of the entire industrial area. The harbour entrance (Fig 2.) and the industrial harbour itself had been neglected for many years. Fully loaded ships could only enter at high tide without grounding on the harbour bed. To meet future requirements calling for access for ships with a draught of 2,80 meters, the port and the harbour entrance had to be dredged to the original depth and the riverbanks had to be restored. Without the riverbank restoration, the harbour would again be filled with sand and sludge within a few years.

The harbour itself was contaminated with 25.000 m³ of polluted sludge that had to be removed. For the refurbishment of the river banks, new building materials should have been brought in to raise the level of the embankments and to protect against waves at high water levels. Both problems were solved with a single solution. Geotextile tube units filled with contaminated sludge from the harbour were used to make the embankments stable and raise the embankments to the required level. The final structure had to withstand the forces of the Ijssel, the fastest flowing river in the Netherlands.

Construction and filling strategy:

The geotextile tubes were filled within 4 sheet pile compartments of 100 meters length each, in total 400 meters. The reason for this construction was quadruple:

1. The sheet piles formed a barrier in which the compartments could be excavated.
2. The sheet piles formed a barrier against the river IJssel, creating a safety margin for rising water levels.
3. The compartments formed a closed barrier to stabilize the geotextile tubes during and after the construction. After the construction the sheet piles were cut off. (Fig 4.)
4. Effluent water from the tubes could be collected in the adjacent compartment and tested before it was discharged to the river in a controlled way.

In each compartment, 4 geotextile tubes, GT 500 D, were filled on a flat sand surface. The sizes of the tubes where based on the project mass diagram and the measurements of the compartments. The tubes were filled in pairs with local material with a solids percentage of 10%. Within 4 days 65 percent dry solids were reached resulting in a very stable infill material of the new dike.

During the placement and filling of these tubes, continuous monitoring took place as the permits by Rijkswaterstaat (Ministry of Transport, Public Works and Water Management) required testing of the effluent water before the water could flow back into the river. The effluent was continuously tested on a daily base for floating sediments, oxygen level and Kjeldahl-N. The levels were set at a high standard (Table 1).

During the whole operation these levels were never exceeded (Table 1.) and the overall impression was that the effluent was cleaner than water from the river IJssel itself.

Table 1. Effluent samples

Parameter	Sample concentration (mg/l)
floating sediment	< 100
oxygen level	> 5
Kjeldahl - N	< 50

Fig 4. Geotextile tubes in place

The harbour and its entrance were successfully dredged and the shoreline was recovered with the use of local sediments. The project was executed within the legal framework and within time and budget constraints. Compared to conventional construction methods, the overall saving was estimated to be 30%, making the use of local sediments and geotextile tubes not only sustainable but also financially very competitive.

3. Project "Dubbele Wiericke"

The challenge to the Waterboard of Stichtse Rijnlanden in the Netherlands was of a more complex nature. It concerned a local canal named Dubbele Wiericke that had been dug in 1360. The dikes of the canal are made of peat and earth. The water level in the canal is higher than the water level in the surrounding areas. The canal stands out in the landscape. The risk of flooding is therefore always present. With the pragmatism that characterizes the people living in these low lands, this potential risk was put to use by the Dutch Republic in the 18th century when flooding areas became part of the defense works, known as the Dutch Water Line. The Dubbele Wiericke was part of this defense line.

The canal also plays an important role in the water management of this low area. Excess water is channeled via the ditches into the canal and out of the polder. Since the canal was silting up, the continued transport of the same volume of water meant that the canal water level was rising. Increased water pressure against the top of the dike could potentially lead to slip-circle failure.

The problems could be solved in two ways: 1. lowering the water level in the area and in the canal by removal of the silt. 2. Increasing the stability of the dike.

Traditionally the dredged sediments would have been dewatered in decantation basins. The cost involved in creating these basins, the transport and off-site disposal of the ripened sludge would already be high. The extra cost of bringing in sand to reinforce the dike, plus the pressure on the limited local infrastructure, made it easy for the water board to go along with a TenCate Geotube® solution presented by the dredging company Bunnik.

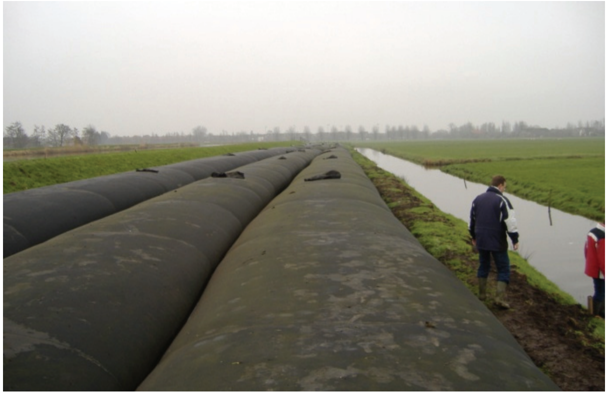

Fig 5. Tubes filled on the dike

They dredged the waterways and used the dewatered sediments to reinforce the dikes with a supporting berm on the outside of the dike (Fig 5.) for extra stability. Using sludge as a construction material can thus lead to shorter project execution times, lower costs, avoiding transport movements by road, and thus contribute to a better environment by lowering the CO2 footprint and reducing social pressure.

5. Project "Herne" Germany.

A different way of incorporating dewatered sludge into the landscape was used in Herne, Germany in 2009. The moat surrounding Herne castle (Fig 6.) was filled with leaves and other organics; in summer, these were the cause of unacceptable odor problems.

It was clear for the job owners, the city of Herne, that simply draining the moat and digging out the trash mechanically could endanger the timber-pile foundations of the castle. A small hydraulic dredge pumped the dirty mass at 150 m^3/hr out of the moat into dewatering tubes. Sludge Subcontractors, a specialist company from the Netherlands, controlled the inline flocculation. The tubes were filled in an excavated area (Fig 7.) in a low-lying part of the park lawns. The effluent that streamed out of the tubes was pumped back into the moat, keeping the water level intact.

After few weeks, the sediments in the filled TenCate Geotube® units had consolidated sufficiently and the tubes were covered with the original soil. The fabric of these particular tubes is made of polypropylene, and, being sheltered from UV influences, there will be no biodegradation. This working method allowed complete avoidance of haulage of the wet sludge, the dewatered sludge and of the used tubes. It was fast, economical and ecologically friendly. The problem was solved without leaving a trace and a previously wet area of the park is now just as dry as the surrounding lawns (Fig 8.)

Fig 6. Herne Castle

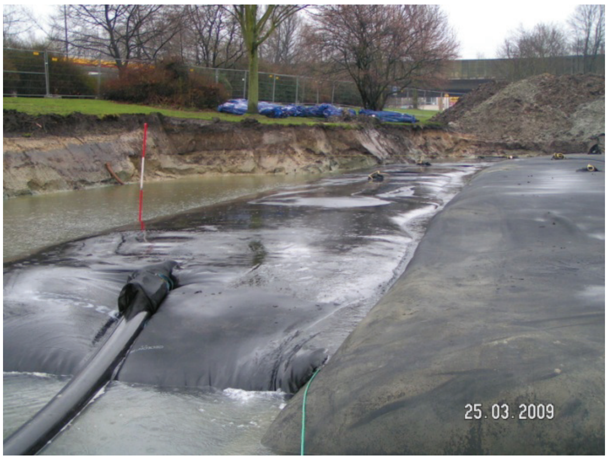

Fig 7. Tubes, at filling and dewatering at site

Fig 8. The containment and dewatering area, just one year after the project started

6.0 Project Tianjin Eco-City, China

The Chinese Tianjin Eco-City development project would turn an existing wetland area into a state of the art urban area. As part of the plan a 3 km² lake that had been filled for 35 years with untreated domestic and industrial waste water needed to be transformed into an ecologically friendly recreational lake. The 5 million cubic meters of contaminated sediments in the lake had an average dry solids content of 10% and were dewatered in TenCate Geotube® systems on three different platforms.

Two test methods were used to assess the suitability of the textile dewatering method. First the initial Rapid Dewatering Test (RDT) indicated the suitability of the fabric, the need for polyelectrolyte and its potential dosage. Then the GDT test that TenCate has developed provided data on the dewatering rate and the final dry solids result that can be obtained. Based upon these tests, and allowing for a sufficient safety margin, the minimum target solids concentration was set at 50%.

The volume reduction ratio was calculated and separate platforms could be designed and built. Each platform was defined by the level of contamination of the sediments it would receive and the specific function that could be given to the dewatered sludge. After dewatering, the heavily contaminated sediments for instance were sent to a secured landfill.

The second platform (Fig 9 + 10.) received the moderately contaminated sediments (mercury contamination between 10 and 20 mg/kg dry weight). 2,400,000m³ of wet sludge was pumped by three dredges at a time, the largest having a capacity of 1,600 m³/hr, the other two “only” 700 m³/hr. Polyelectrolyte was injected inline before the sediment slurry arrived at the tubes. The tubes were stacked into several layers, limiting the platform footprint and providing sufficient capacity for the 400,000 m³ consolidated materials remaining after dewatering. The effluent was returned to the lake.

Fig 9. Tianjin Eco-City site

Fig 10. Tianjin Eco-City site

After the sediments had dewatered the tubes were covered first with a soil cover to smoothen the surface, then by an HDPE geomembrane liner which was finally topped by two layers of soil. The mound that was built up from contaminated sediments is now integrated in the natural landscape of this new city, and offers great views over the lake whose water is cleaned by a waste water treatment plant.

A project of this size and complexity can only be realized with reliable partners that combine tube dewatering know-how with knowledge of platform layout and stacking based on longtime experience with these practices worldwide.

7. Project Embraport Brazil

A large container and bulk cargo terminal is being constructed in the Port of Santos, Brazil. When completed, early 2014, the terminal will be the largest privately owned port facility in Brazil with over 600,000 m² dedicated to container storage. To develop the site, large quantities of imported fill would have been required in addition to dredging and disposal off site of large volumes of contaminated sediments. In total this represents a significant cost to develop the site. Allonda, Brazil and TenCate engineers developed an alternative solution based on using the dredged contaminated sediments to be dewatered and contained on site in large geotextile tubes (Fig 11). The material would be environmentally secured permanently within the geotextile tubes over which the container storage yard (Fig 12) would be constructed. In addition, this solution would eliminate the need to dispose of 600,000 m³ of contaminated sediments offsite and to import 450.000 m³ of selected fill into an area that was difficult to access. The alternative design greatly reduced the construction cost.

Fig 11. Tube dewatering site, completed and started with overburden placement early 2012

Fig 12. Project completed end 2013

8. Conclusions

1. Geotextile containment solutions have been successfully applied to manage and dispose of contaminated sediments in projects internationally.
2. Lack of knowledge about the possibilities of silts/sediments in combination with, for instance, stabilizing, makes some engineers reluctant to use these new, creative techniques
3. Geotextile containment solutions have gained acceptance in recent years to solve a wide variety of problems related to management and disposal of contaminated sediments.
4. Re-use of dredged sediments can lead to substantial savings to project owners.
5. Dredged sediments should be seen as valuable building materials, rather than as waste materials.

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