Abstract

Since 1990 HAM-VOW has been working to develop the technical and economic possibilities of constructing building sites for housing on the very soft seabed in the IJ-meer, close to the city centre of Amsterdam. In November 1991 the Municipality of Amsterdam and HAM-VOW started preparations for the construction of a pilot island. One of the possible, economically feasible methods selected was to cover the soft seabed material with geotextile on which sand would be placed in thin layers with very narrow tolerances. However, this way of placing sand in thin layers required the development of new techniques. To test these new techniques it was decided to construct a small island as a pilot project.

In this paper details of the manufacture and placing of the geotextile are discussed. A special pontoon was built for the placing of the textile. This pontoon was equipped with computer controlled winches which enabled the pontoon to move along a defined line with a maximum tolerance of 0.5 metres (accuracy of positioning system included). In this way the required overlap between the separate textiles could be guaranteed in an economical way.

As soon as the geotextile was in place, the pontoon had to be converted into a spraying pontoon. The sand-water mixture was pumped from 1,500 m³ barges by a barge unloading dredger (Sliechter 26; total output of engines 4,780 kW), through a partly submerged and partly self-floating pipeline with a total length of approximately 1,300 metres, to the spraying pontoon. To be able to spray in thin layers with a high production-output, the pontoon was equipped with several control devices. The computer controlled winches of the pontoon were used to move it along defined lines at a speed related to the concentration and mixture-velocity of the sand-water mixture. In this way three layers were sprayed up to the existing water level with thicknesses of successively 0.7, 0.5 and 0.7 metres.

To be certain all demands were met and to be able to evaluate the whole process, the relevant process parameters were logged on the computer at regular intervals (mixture-flowrate and mixture-concentration, offset from line, and so on).

From a dredging point of view, this project demonstrated that developments in production automation in recent years enable an economical performance with accuracies never before attained.

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Introduction

As part of the development of IJ-burg (a planned residential housing area next to Amsterdam), a pilot project in the IJ-meer had to be executed. The works involved of the construction of a small island in the shallow
areas of the IJ-meer, east of Amsterdam. The pilot project served two main purposes:
1. to check whether the subsoil behaved as calculated; and
2. to test the proposed equipment to be used for the construction of the new housing area.

Because the subsoil in the area consisted of very soft material, especially the top layer, and disturbance of the subsoil had to be avoided, it was necessary that a geotextile should first be placed on the bottom of the IJ-meer. This geotextile was then covered with thin layers (0.50-0.70 m) of sand. To avoid excessive expenditure for this project, a pontoon was designed and built which was able to place the geotextile and which, after minor conversions, could also serve as a spraying pontoon to place the sand.

**Design of Equipment**

**Design Conditions**
Design conditions had to be determined for, first of all, the laying of the geotextile and secondly, the placing of sand.

**Laying of Geotextile**
The following requirements were applicable to the laying of the textile:
- The geotextile should be placed in lanes with a minimum width of 25 metres.
- The overlap between two lanes should be 2.50 metres.
- The maximum horizontal tolerance should be within 0.50 metres of the defined line.
- The placed geotextile had to be ballasted with sand as soon as possible.

**Placing of Sand**
The following requirements were applicable to the placing of sand:
- The sand had to be placed in layers with a thickness of 50 to 70 cm.
- The tolerance in placing of the sand layers was $-15/+10$ cm.
- The last layer had to be placed at a water depth of approximately 70 cm.

**Design of Multifunctional Pontoon**
Since one of the purposes of building this test island in the IJ-meer was to test the equipment for both placing geotextile and sand, it was necessary that the equipment was designed to handle large quantities. This meant the laying of 25 metres wide geotextile at a minimum laying speed of 2 m/min and attaining an estimated sand production of approximately 1,000 m$^3$/hour. The tolerances mentioned above made it necessary that the pontoon was moved by constant tensioning winches. Furthermore it was anticipated that these tolerances could not be met by operating these winches manually. Therefore the shifting of the pontoon had to be controlled by a computer.

To handle the 25 metre wide geotextile it was necessary that the pontoon had a length of 34 metres. For stability reasons and in order to reduce the draft to less than 50 cm, the width of the pontoon was 17 metres. To place the sand a chute was designed which had to be capable of spreading the sand over a width of 12 metres. The velocity in the chute had to be maintained such that sedimentation did not take place on the chute. A side and top view of the pontoon is shown in Figure 1. The pontoon waiting to lay the geotextile can be seen in Figure 2.
Construction of a Pilot Project Island in IJ-meer

Construction of Underwater Part of Test Island

The Geotextiles
The three different types of geotextiles were manufactured according to special requirements, and were then prepared to be transported by road to the work site. At the work site they were placed on the seabed by a laying pontoon.

Fabrication of Textiles
In the factory of Nicolon at Almelo, threads made of polyester were woven into mats approximately 5.10 metres wide and of the required length (60 or 160 metres). These mats were sewn to produce 25 metre wide strips. These new mats were rolled around a specially made pipe (diameter 800 mm and length between flanges 26.50 metres). The finished rolls were covered with a sheet to protect the geotextile during transport.

In this way three different types of geotextiles were fabricated:
– Stabilenka 200/45
– Stabilenka 400/50
– Geolon 15

Transport of Textiles from Factory to Work Site
The rolls were transported from Almelo to Amsterdam by road. One special transport truck could load one roll. Two rolls at a time were delivered at Amsterdam, unloaded from the trucks, and placed in the jibs of the transport pontoon. The transport pontoon was towed from the quay wall to the work site and the rolls were picked up from the transport pontoon by two hydraulically manipulated jibs on the laying pontoon.

Placing of Textiles
The laying pontoon was moored on a six points anchoring system. To meet the required accuracy, good anchoring was very important. Because of the poor anchoring soil conditions it was decided to place anchor piles around the proposed island. However, a few places could not be used to place anchor piles so in these areas two 6.5 tons Stevpris anchors were used. The geotextile was fixed to an anchor beam (see Figure 3) by means of ropes and the anchor beam was lowered to the right position on the seabed.
At both ends of the anchor beam two stakes with flags were placed to check the position of the anchor beam at the start of the operations. Once the anchor beam was in the correct position the pontoon moved forward to place the geotextile (see Figure 4).

The pontoon was shifted by means of its six winches. To stop the steelwires sinking to the bottom and causing damage to the already placed geotextile, small floaters were placed underneath the wires. All winches were controlled by the computer in order to stay within the accepted tolerances. The data from the positioning systems (Axyle radio positioning system and geodimeter) were fed into this computer which manoeuvred the pontoon along the predetermined line at the predetermined speed. The dredge master could follow the laying operation at the computer displays and, if necessary, overrule the computer in case of emergencies.

Ballasting of Geotextiles
The polyester of which the geotextile was fabricated had a specific gravity of 1,380 kg/m3 and, taking into consideration that some air bubbles were trapped into the textile, this might tend to float. Therefore it was decided to ballast the geotextile. For ballasting purposes a pontoon with a hydraulic grab crane on board, was coupled to the laying pontoon. About 150 m³ of sand was stockpiled either side of the crane. When the...
pontoon moved over the geotextile the crane placed the sand on it to ensure that it remained on the bottom (Figure 6).

**Placing Sand in Thin Layers Using a Spraying Pontoon**

After delivery of the sand to the work site from a borrow area, the sand was placed in three layers by a spraying pontoon.

**Delivery of Sand to Work Site**

The borrow area was situated in the IJ-meer, between the islands Pampus and Muiderberg. Two self-propelled barges were used to transport the sand from the borrow area to the site.

The barge unloading dredger *Sliedrecht 26* (total output of engines 4780 kW) was situated north of the breakwater along the navigational channel and discharged the sand-water mixture from the barges through a 1,300 metres partly submerged and partly self-floating pipeline (diameter 700 mm), to the spraying pontoon.

**Placing Sand in Thin Layers**

The spraying pontoon moved by means of 6 computer controlled winches along predefined lines, at a speed related to the concentration and the mixture-velocity of the sand-water mixture (Figure 7). The four side winches kept the pontoon within the allowed horizontal offset and the bow and stern winches were used to move the pontoon along the defined line. The pontoon progressed in a direction parallel to the short side of the pilot island. The bow and stern winches were also controlled by the PA-computer.

The information used by the computer to determine the progress of the pontoon along the line was:
- the spraying width for each pass.
- the desired layer thickness to be sprayed.
- the measured sand water mixture velocity.
- the measured mixture concentration.

The computer also took the relevant soil parameters of the sand into account. To be certain all demands were met and to be able to evaluate the entire process, the relevant process parameters were logged on the computer at regular intervals. A computer programme was written to plot the relevant parameters into graphs (Figures 8 and 9). The mixture velocity and the mixture concentration were measured onboard the spraying pontoon. For this purpose a flow meter and a density meter were mounted in the spraying pipe of the pontoon. To achieve a continuous uniform spraying process it was important to maintain a constant production rate for the *Sliedrecht 26*.

The following actions were taken to achieve a constant production rate:
- Installation of a "flowcontrol" to keep the mixture velocity at a fixed level.
- The mixture concentration was controlled by the dredge master of the *Sliedrecht 26*. During the spraying of the first two layers the dredge master tried to keep the mixture density at 1.25 t/m³.

For positioning and line definition purpose the longitudinal side of the island was divided into survey lines with a spacing of half a metre. The spraying width determined for each pass was 12 metres, hence the distance between the separate spraying lines was 12 metres (24 survey lines).
During the spraying operation the pontoon moved along those lines defined in the survey computer. When the sand-water mixture left the spraying mouth a density current was formed underwater in which, at a certain point, the sand settled down under the influence of gravity. From survey records and calculations this sedimentation-length proved to be approximately 20 metres. This was taken into account by shifting the starting and finishing point of the line to be sprayed over 20 metres. To keep the sand within the specified working area of the pilot island certain procedures were prepared before commencement of the works. The main factor, when moving to another survey line, was to reduce the density (which was controlled by the dredge master of the Sliedrecht 26) to approximately 1.1 t/m³, which resulted in relatively low desired progress velocity of the spraying pontoon.

When preparing the works, a water level of 0.40 m -NAP in winter time was assumed and an average seabed level of 1.95 m -NAP, resulting in three theoretical spraying layers of 0.5, 0.5 and 0.70 metres successively. Within these figures the anticipated settlements were taken into account. During the insurvey the actual seabed level varied between 2.10 m -NAP and 1.70 m -NAP. Based on this in-survey the actual layer thicknesses to be sprayed were fixed at:

- Layer 1: 0.7 metres over 2/3 of the surface of the pilot island and 0.5 metres over the remaining 1/3 of the island.
- Layer 2: 0.5 metres over 2/3 of the surface of the pilot island.
- Layer 3: To fill the total surface of the island up to the existing water level.
When spraying the third layer the working method deviated from the working method used to spray layer 1 and 2. This will be described below. In the time schedule the anticipated time required to execute the placing of one layer was one week. A consolidation time of three weeks was anticipated before commencing the spraying of the next layer. The placing of the sand led to increased water pressures in the underlying stratum. To measure the actual water pressure three piezometers were installed in the mud layer at a depth of 3 to 3.5 m -NAP. If the readings of the piezometers decreased to an acceptable level, the spraying of the next layer could commence. During the actual work the consolidation time was indeed three weeks.

**First Layer**

The first layer comprised the entire surface of the pilot island (335 m * 160 m). The actual execution time for this layer was seven days. In the first layer a total amount of 33,500 m³ of sand was sprayed, divided over 27 spraying lines. The average output of the *Sliedrecht 26* was 920 m³/hour (with a maximum bulk production of 2,200 m³/hour).

**Second Layer**

The second layer comprised 2/3 of the surface of the pilot island. Due to the shape of the slopes of the island the length of the spraying lines was decreased from 160 to 115 metres. The actual execution time for this layer was three days. In this layer a total amount of 11,000 m³ of sand was sprayed, divided over 17 spraying lines. The average output of the *Sliedrecht 26* was 800 m³/hour. Due to a storm during the execution of this layer the water level was lowered to 0.70 m -NAP, resulting in the pontoon hitting the seabed at several places.

**Third Layer**

Originally, it was intended that the third layer would be placed by using the automated system. However, it was decided that the last layer would be placed by adopting a different method. Since this last layer had to be placed up to the water level it was possible to check the progress visually. It was also possible to achieve a greater width of the placed sand by swinging the pontoon somewhat. In this way a width of 30 metres could be achieved. Another advantage was that the production could be increased. Mixture density was now higher than 1.3 t/m³. Only when the pontoon was shifted to another line the mixture density had to be decreased. The average production during construction of this layer was 1,150 m³/hour. During placing of sand the pontoon was travelled backwards only. The last layer covered the total island with a length of the lines of 90 metres. In 8 days 41,500 m³ of sand was placed. Some delay was encountered due to strong southwesterly winds, resulting in a water level which was too low to operate the spraying pontoon.

**Conclusions**

Generally speaking, this project has shown that it is possible to move a pontoon on anchors along a predetermined line within very narrow tolerances.

**Placing Geotextiles**

The required tolerances for placing a geotextile along a predetermined line have been met. A representation of an actual line “sailed” is shown in Figure 10. The losses in width for the geotextile have been greater than expected (Table I).

**Placing Sand Using a Spraying Pontoon**

For the greater part of the project (70% up to 90% of the sprayed surface) the required tolerances in the thicknesses of the layers of the sand were met. The actual maximum tolerances achieved are shown in Table II.