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Sub-Surface Dredging: An Economic and Environmentally Friendly Technique for Lowering Ground Levels

Abstract

A new technique in soil treatment has recently been introduced. Following the successful development of the BeauDrain® vacuum consolidation system, Boskalis has now developed another new dredging technique called BeauDredge®. Clean sand is extracted from underneath the (unmarketable) top layer and consequently the existing ground level is lowered more or less undisturbed. A pilot project at the Ketelmeer (The Netherlands) has demonstrated that the technique is highly suitable for deepening or constructing navigation channels by dredging under (contaminated) upper layers. The technique can also be used for various other "soil jobs" in hydraulic engineering.

Introduction

An entirely fresh approach has been chosen for developing the new "keyhole" dredging technique. In The Netherlands, many of the dredging related problems concern nautical soil. In other words, navigation channels need to be dredged to enable vessels to pass. But often the bottom consists of contaminated or unmarketable sediment that needs to be removed and treated or disposed of.

"Try to lower the ground level by extracting useable sand without spreading deposits". With this instruction in mind a team of experts set to work. They conceived a technique to lower ground levels and deepen channels by dredging sand under (contaminated) upper layers, so preserving the properties and composition of that layer. A prerequisite in developing this innovation was that it had to be practical to implement and competitive with respect to state-of-the-art dredging techniques.

While this technique was being developed, a case study was also conducted into the economic feasibility. Calculations were made for both a short-term scenario (small-scale deployment) and a long-term scenario (large-scale deployment). The calculations also included the economic value of the extracted sand. When it was found that sub-surface dredging was both technically and economically feasible, the decision was made to test the innovation in practice.

Prototype Testing

The BeauDredge® system was tested for the first time in 2003 on the banks of the sand borrow pit Engelenmeer in Vlijmen (Noord-Brabant). With a newly built prototype extensive ground level lowering trials were carried out on land. Subsequently, in the spring of 2004, a ground level lowering trial was carried out in Herfterwetering (Figure 1). Under contract from the Groot Salland district water board, the ground level with a surface area of approximately 2 hectares was lowered by 0.5 m. The area was subsequently used for water retention and nature development purposes. The sand produced by the sub-surface dredging was used elsewhere. An advantage of sub-surface dredging is that the properties of the upper layer are maintained and the "bed remains bed" principle is preserved. Following the encouraging results, the dredger Gunfleetsand was refitted for this purpose for the application of BeauDredge® on water.

Ketelmeer Dredging Trial

In collaboration with The Netherlands Directorate-General for Transport, Public Works and Water Management (RWS), IJsselmeer Department, Boskalis implemented a pilot project to investigate whether the projected Hanzerak-West deepened navigation channel could be constructed at the Ketelmeer in a polluted bed, with the extremely expensive remedial dredging being postponed or even omitted. A mutual aim was that both parties, initiator and partner, should be able


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Peter van der Linde

Peter van der Linde completed his studies at the Higher Technical School (H.T.S.) in Vlissingen, The Netherlands in Civil Technique in 1981. He joined Boskalis as a project leader, and was deputy area manager in Singapore until 2001. He is presently manager in charge of a number of projects in Germany, shore protection in Singapore and the cleanup of the Ketelmeer.


Dick Bodegom

Dick Bodegom commenced his career in 1974 as a hydrographic surveyor on the North Sea for the Netherlands Directorate-General for Public Works and Water Management (Rijkswaterstaat). In 1975 he moved to Adriaan Volker, and in 1980 he joined Boskalis, working on numerous dredging and shore protection projects as superintendent and project manager throughout the world. Since 2000 he is focussed on Research and Development at Boskalis.

to gain insight into the background of the technique. They opted for a joint monitoring contract. This saves costs and ensures involvement from both sides.
The anticipated result of the pilot project (product) was to lower a part of the navigation channel at the Ketelmeer to the required depth.
The following preconditions were specified beforehand in a soil removal permit:
- bed lowering depth tolerance approximately 1.5 m;
- overflow during sub-surface dredging (discharging water-sand mixture) was not permitted; and
- clean extracted sand has economic value and is to be used as fill material (constructing a nature conservation island).

Implementation

RWS made a 60 x 160 m section of the navigation channel at the Ketelmeer available for the pilot project (Figures 2, 3 and 4). Geologically the IJssel Delta is an interesting area. In the Pleistocene Period, the IJssel was a fast flowing river, which brought in coarse sand that settled in the Ketelmeer. In the later Holocene Period, the river started to meander and the flow velocity declined resulting in less and finer sand and later clay with peat formation being introduced. The unusable upper layer of clay and peat is approximately 3 m thick. The sand was extracted at a depth of approximately 6 m below bottom level (approximately 10 m below the Amsterdam Ordnance Datum).
This depth lies roughly on the transition of coarse and fine sand. The grain size of the dredged sand has a D_{50} of 191-335 µm. According to the requirements of Standard RAW 2000 this sand is suitable as drainage sand (partially) and fill material.

Since overflowing was not permitted during the pilot project, the total water-sand mixture was discharged into hopper barges of approximately 800 m^3. In order to prevent overflow at all the barge was filled to approximately 600 m^3 (150 m^3 sand and 450 m^3 water). The barge was then transported to the discharging location in the mouth of the River IJssel approximately 5 km away from the dredging site. Here the water was pumped into a settling basin and the sand was used to construct a nature conservancy island.

Monitoring

A comprehensive monitoring programme was drawn up to help evaluate the trial properly. Any direct and indirect effects on the environment were examined. The following parameters were established before, during and after the trial:
- soil structure and quality;
- water depth;
- suspended sediment (quality and quantity);
- water quality;
- groundwater level and quality (including salinity);
- ecology of the water bed.

The measurements were carried out according to a monitoring and measurement plan drawn up jointly (by initiator and partner). External quality control was supervised by the Deventer engineering consulting firm of Witteveen en Bos.

Besides the environmental effects, several process parameters of the dredging process were measured including:
- flow rates of the dredging system;
- grain-size distribution of the extracted sand;
- density of the water-sand mixture.

The provisional results show that the trial is running according to expectations. One of the provisional conclusions is that BeauDredge® causes negligible turbidity and that the groundwater level in the surrounding polders is not affected. Moreover, it was found that the (remaining) soil layers do not mix. The dredged sand is used in a project for the construction of a nature conservancy island (creating "work with work"). During the process, as much experience as possible is being gained with different process variations so that on evaluation, the possibilities of the new sub-surface dredging technique become obvious.

Conclusions

A number of application potentials of BeauDredge® have been identified. To date, the keyhole dredging technique has been used for constructing a retention basin and deepening a navigation channel. In the future, projects could also be carried out for profile widening in the context of the "Room for the River" project (a governmental plan to invest 2 billion Euros to protect parts of the Rhine and Maas against flooding and other

Figure 1. The BeauDredge® during construction of retention basin at the Herfterwetering.

Figure 2. The BeauDredge® at the pilot project, the deepening of the navigation channel Hazerak-West in the Ketelmeer.

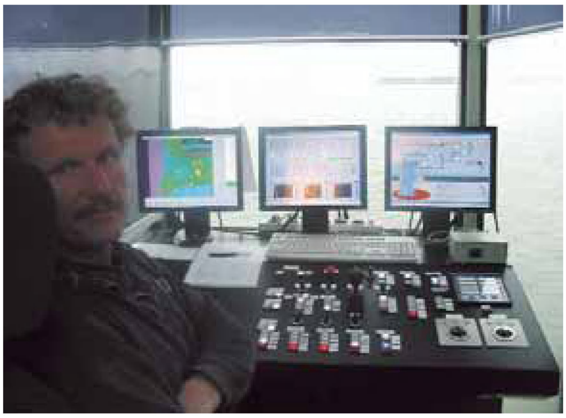

Figure 3. A view of the control panel of the BeauDredge® installation.

Figure 4. A close up of the BeauDredge® installation.

consequences of high water levels) and for improving water quality. To this end, sand below the eutrophied (food-rich) waterbed is dredged and the fine fraction used as cover for that same waterbed. This is possible by allowing the overflow to settle in a controlled method or by using an advanced distribution method.

The technique can be further used for selectively extracting high quality sand (such as sand for industrial purposes), below silt that purposely has been discharged into deserted sand borrow pits or below natural silt deposits.

There are other good opportunities for this technique as well. In areas where for example sea grass or other vulnerable bed vegetation occurs, it is possible to dredge without causing appreciable damage to the flora and fauna. BeauDredge® facilitates a number of new hydraulic engineering jobs that were previously technically impossible and economically unfeasible.

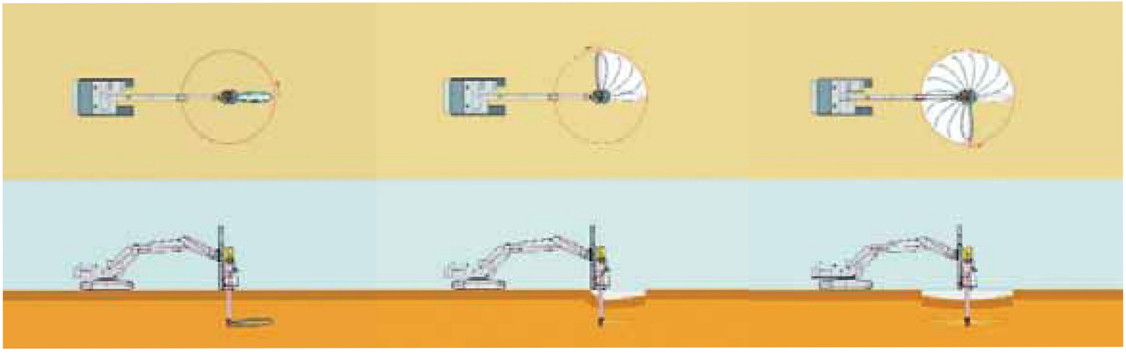

Figure 5. Steps 1 through 3 show the extraction of clean sand in circles from the layer underneath.

Application of the BeauDredge® Technique

The new technique, which is called keyhole dredging or BeauDredge®, has been developed in-house in cooperation with various departments at Boskalis. Existing sub-surface techniques have been upgraded, resulting in a method where clean sand is extracted from under an upper layer without any mixing or spreading the upper layer. During this process, the upper layer settles in a controlled manner, while its character and properties remain intact ("bed remains bed"). As a result, bed lowering can in many cases be achieved without remedial dredging being necessary, while the extracted sand can be used as construction material.

In order to gain insight into the geological make-up, soil investigation and soundings are carried out beforehand. This data is indispensable when preparing a dredging plan. Based on the type of sand, the density, and so on, the area to be lowered is gridded and the information saved to a central computer. In the different process stages operators can view the information on their own monitors. DGPS is used for positioning.

In order to reach deeper sand layers, a displacement drilling method is used to drill the dredging tool – of which the suction mouth is closed during this phase – through the upper bed layer. A standard vertical drilling rig is used of the type used for constructing foundation piles. Once the target depth has been reached, a horizontal (or other required angle) jet is used to erode the sand. From the parameters set (such as pressure and flow rate) it is possible to determine when the optimum horizontal penetration depth has been reached. The dredging tool is then rotated slowly until the circular layer of sand around the tool has been extracted (Figure 5). During the dredging process the flows of jet water and the extracted water-sand mixture are kept equal. This prevents a blow-out or collapse.

Following dredging, gravity allows the upper layer to settle gradually without changing the character and properties or mixing the soil layers. A full cycle takes approximately 35 minutes. Indicative production is 150 m^3 sand per hour.

During the dredging operation, regular measurements are taken: soundings, sub-bottom profiling, and so on. The results are used for the process control and quality control of the dredging process. In addition, the data is saved to a database to build up a knowledge base with process parameters for the different sorts of sand extracted by means of keyhole dredging.