TECHNOTES

Prof. Dr ir J.F. Agema Prize for Hydraulic Engineering 2005

The Prof. Dr Ir. J.F. Agema Prize 2005 was awarded at the Hydraulic Engineering Symposium on the 12th of October 2005, in Amersfoort, the Netherlands. The prize is named for prof.dr.ir. Jan Agema, a hydraulic specialist who rose from secondary vocational school to professor, and was responsible for a number of significant projects, such as the first Maasvlakte and the restoration of the dikes after the flood disaster in the south of the Netherlands in 1953. The prize is presented every five years by the Division of Hydraulic Engineering of the Royal Dutch Institute of Engineers.

The theme of this year's Symposium was "Innovation" and the Agema Prize was presented to the storm-surge bellow barrier Ramspol. The bellow barrier is located between Kamper Island and the North East polder. The structure serves to protect the hinterland against the wind set up at Lake IJsselmeer and Lake Ketelmeer with an accepted failure probability of 3.5×10^{-4} /year. Thus the water levels at the Zwarte Water and Zwarte Meer are controlled to an extent that design water levels of the surrounding dikes are not exceeded. The client, Waterschap Salland, awarded the design, build and maintain contract to BAM Civiel, who asked its subsidiary Delta Marine Consultants bv to make the design. Bridgestone served as a sub-contractor for the cloth of the bellow. According to the contract the structure has to be maintained by the contractor for a period of 10 years.

The storm-surge barrier consists of three identical inflatable bellows. The crest level of these inflatable weirs lies 8.35 m above the sill, the crest length at the top is 80 m and at the sill 60 m. The width at the sill is 13 m. The closure operation is completed in one hour. Lowering the weirs after the flood takes 3 hours.

The weirs are inflated in a very innovative way. After a small amount of air has been entered into the bellow, it unfolds as a result of the buoyancy of the expanding air, and fills itself automatically with water. Because the bellow is partly filled with water the buoyancy force on the foundation is limited and consequently the foundation can be constructed lighter and cheaper. The opening of the barrier requires only a limited water pump capacity because the ambient water presses the air out of the bellow.

The bellow is constructed from 16 mm thick rubber reinforced with nylon fibers. The nylon reinforcement leads the forces to the foundation in cross as well as longitudinal section. The large loads in the reinforced cloth are introduced into the concrete sill by specially designed clamps. Maintenance of the bellow is facilitated by the fact that is can also be filled with air to allow human visual inspection.

The storm-surge barrier Ramspol exemplifies an inventive and flexible application of hydraulic engineering in an innovative contractual setting encompassing design, construction and maintenance.

Soft Soil Improvement (SSI) Technique During the Construction of an Underwater Bund Built on Dredged Material in the Doeldock, Antwerp, Belgium

The Doeldock, located on the left bank harbour of the port of Antwerp, was constructed in the late 1970s and 80s and was destined for the (petro)chemical industries. No quay walls were built, only slopes ideal for chemical carriers to berth at jetties and unload their cargo. Owing to changes in legislation and economics, this never happened. At the same time underwater cells at Doeldock were dredged to store dredged materials from maintenance dredging of the River Scheldt. This resulted in an unused dock, lacking quay walls, with soft dredged material below the bottom. When construction of the new tidal dock for container traffic, Deurganckdock, was underway, and no storage space was available for the large amounts of dredged soil, the Doeldock became a storage place. To limit the negative impacts to the environment, a separation between the site for fill and the rest of the dock had to be made.
Using the patented SSI Technique for the foundations and modifying standard dredging equipment, a 25 m high bund (from –15 50 +10 TAW) was constructed on top of an 8 m thick layer of dredged soil.

INTRODUCTION

At the Port of Antwerp (Belgium) on the River Scheldt, the unused petrochemical harbour Doeldock has been utilised instead for underwater stockpiling of dredged material from the harbour maintenance dredging works. At the present time a 27 m high embankment has to be built on the 8 m thick layer of these recently deposited sediments in the partly abandoned Doeldok. For environ-mental reasons, removal is not possible. Taking into account the large dimensions of the construction, the very soft foundation layer and the strict timing of a year and a half construction period, this provides an exciting engineering challenge. To accelerate the construction time and to improve the stability special techniques were implemented in the design: Deep Soil Mixing (DSM) to stabilise the toes of the embankment and geotextile reinforcement at the water-sided slope of the embankment.

Site Description

The abandoned dock has a water depth of 20 m (+4 to –16 TAW; TAW being the official Belgium leveling datum) and has a width at water surface of approximately 550 m. The underwater storage cells were deepened in the bottom and have an approximate depth of 8 m (-16 to -24 TAW).
The excavated layers consist of sand that was used for harbour development projects. Below the bottom of the cells only a think layer of sand remains on top of a stiff highly overconsolidated tertiary clay (the Boom Clay). The sand layer remaining between the slurry and the stiff clay is partly disturbed from dredging operations. The main problem of the construction of the embankment is the very soft dredged material deposit in the underwater cells that were realised during the past decade.

Project Description

The main construction scheme can be described as follows;

1. Soft Soil Improvement under the toes of the embankment in zones of 65 m and 57 m wide;
2. Application of a first sand layer approx. 1 m thick over the whole construction zone by means of sand spraying (over the improved as well as the not improved zones);
3. Installation by means of a heavy lifting floating crane of the first layer of geocontainers with the geotextile affixed;
4. Application of a 2 m thick sand layer behind the geocontainer on the geotextile by sand spraying.

The last two steps are repeated 9 times at 2-month intervals to allow for partial consolidation and improvement of the shear strength of the soft layers.

The stabilisation of the dredged material cell underneath both toes of the embankment was needed to allow for the construction of the slopes of H:2.5 to V:1 on the very soft deposits without squeezing or slope failure. At the steepest slope side (which is the future water side of the embankment), the geotextile reinforcement will be applied. During and after the construction of the embankment, the isolated part of the Doeldock will be filled with sand from the dredging of a new dock open to the river Scheldt, the Deurganckdok.

Soft Soil Improvement (SSI) Technique

The Soft Soil Improvement technique, developed by Hydro Soil Services, member of the DEME group, was a cost-effective stabilisation solution.
An innovative and scientific in situ means of stabilising and improving possibly contaminated soft or very soft marine soil, the technique increases the bearing capacity of soils for construction works and immobilises contaminated marine sediments.

SSI technique uses simultaneous hydraulic and mechanical blending to create a pre-determined configuration of soil-improved columns. A mixing blade is fixed to a central drilling rod. The leading edge and sides of each blade have an array of high pressure mixing nozzles, while the trailing edge is equipped with low pressure grouting nozzles. As the blade moves in a corkscrew motion, grout is injected through each set simultaneously, providing both hydraulic and mechanical mixing and creating cylindrical columns.

The type of binding material, blade design, rotation and vertical seed, injection pressures and other parameters are determined according to soil characteristics and the design objectives of the project.

The SSI technique offers a wide range of possibilities to realise a stabilisation using different soil improvement patterns: SSI columns in a regular, triangular or square pattern with a soil improvement ratio of minimum 25%, wall type stabilisation up to full mass stabilisation, which depends on the design requirements.

A total of 3100 columns with a diameter of 1.9 m and an average length of 8 m have been executed during the entire project. To improve stability some extra rows of columns were executed between the normal grid-pattern at the extremities of the improved zones so as to realise small continuous walls perpendicular to the embankment length axis.

Equipment

The grout injection mixture was prepared on shore, at a specially designed land installation, and then pumped to the working platform by means of floating pipes. The project was executed with two drilling towers from a jack-up platform. State of the art positioning systems ensured that the tower was precisely located at each column position.
A mixing blade of 1.5 m wide was used and the position of the injection nozzles guaranteed the realization of the improved soil columns with a diameter of 1.9 m. The rotating arm was drilled into the subsoil down to the predefined depth or to a predetermined torque couple. All drilling and injection execution parameters were automatically monitored.

Performance

The quality of the SSI columns was tested by means of in situ cored samples. The results of the laboratory testing on all core specimens confirmed an UCS value which was far in excess of the require UCS value of 370 kPa according to the basic design.

Construction of the Embankment

The sand that will be used for the filling operations comes from the dredging works for the construction of the Deurganckdok. The sand is selected on basis of fines content, so as to obtain optimum results when hydraulically placed. The choice of the right sand material for the underwater filling operations is very important so as to be able to guarantee the shear strength characteristics needed for the stability of the embankment itself.

From the on-land temporary realised stock, the material will be brought to a sand pump so as to deliver continuous flow towards the sand spreader vessel, which has a fall pipe with a 12 m wide horizontal spreader beam. A first equalisation layer of approx. 1 m thickness will be placed all over the area where the embankment will be built and after that, the first layer with geocontainers and geotextiles is placed and then a sand layer of 2.0 m thickness is laid down.

Several special types of equipment were constructed, by modifying existing equipment to meet the conditions described by the designer. The floating booster station DC401 was modified with a bunker and jetting sytem to turn the excavated sand into a pumpable mixture of sand and water. The bucket dredger Adriatico was adapted by removing the bucket chain and placing a pipeline on the ladder leading to the spreader at the bottom of the ladder. This helped with spreading the pumped sand evenly which is very important so as to prevent the soft soil underneath from becoming unstable and creating a mudwave in the body of the embankment.

The Adriatico was also used for unwinding the geotextiles, and for the leveling of the spread sand, by mounting a bedleveller underneath the ladder.

Monitoring equipment was placed under the embankment to evaluate the staged construction scheme. The monitoring will verify the deformation behaviour and degree of consolidation of the soft clay material. It is of utmost importance in a staged construction project that the in situ behaviour of the material is checked with the theoretically assumed behaviour.

CONCLUSIONS

The practical execution of an embankment on very soft man-made deposits as described here presented a challenge. Utilising the patented Soft Soil Improvement method proved to be very successful in stabilising the soft deposits so as to be able to build 27 m high (primarily underwater) embankment on top of it.

For further information about this project see the paper by H. De Preter and S. Vandycke in the Proceedings of WODCON XVII 2004, Hamburg, Germany. H. De Preter works at the Flemish Government, Department Maritime Access, Belgium and Stefaan Vandycke, is at the Department Applied Development, Dredging International, also in Belgium.