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Renovation of a lock by means of special techniques
Techniques spéciaux pour la restauration d'une écluse

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ABSTRACT: At a lock for 1350 ton vessels on the Albertcanal at Olen, with regular time intervals of a few years measures had to be taken to avoid exessive settlements of the lock bottom slab and cracking and deformation of the walls. These measures consisted mainly of grout injection under the slab. Special techniques were used to solve the problems in a permanent way :
- The installation of relief wells underneath the bottom of the lock.
- The installation of an upwards cut-off screen by means of jet-grouting.
- The strengthening and prestressing of the existing walls by means of steel bars anchored in jet-grouting columns.

RÉSUMÉ: Une écluse pour des bateaux de 1350 tonnes présentait des désordres. Afin d'éviter que des tassements excessifs du fond de l'écluse et une fissuration et déformation des murs se produisent, il était nécessaire de procéder régulièrement à des remédiements. Ces remédiements consistaient normalement d'injections sous la dalle avec du ciment. Afin de résoudre les problèmes d'une façon définitive des techniques spéciaux ont été utilisées, notamment:
- l'installation de puits de décharge en dessous du fond de l'écluse
- l'installation d'un rideau étanche du côté amont et par la méthode de jet-grouting
- le renforcement et la mise en précontrainte des murs de l'écluse à l'aide de barres d'acier ancrées dans des colonnes de jet-grouting.

1 INTRODUCTION

In the beginning of the century in Belgium the Albert Canal was constructed to connect the river Maas with the port of Antwerp. Along this canal several locks had to be constructed with a water level difference of 10 m each. These locks consist of two side-by-side locks of 10 by 150 m constrcted as concrete U-shaped closed structures.

Now the Albertcanal is the heart of one of the mayor industrial regions of Belgium and recently new and bigger locks were constructed next to the old locks, which anyway have to remain fully operational due to the heavy traffic.

However, several of these old locks show serious signs of deterioration, concrete fissures, large settlements and tilting of the lock walls and lock structure in total. It was decided that a large scale repair program of the locks was neccessarry and urgent.

The first lock to be repaired was the lock of "Olen" because the bottom slab showed serious level differences and large cracks in the walls combined with movement towards the inside of the lock. The global stability of the lock was doubtfull. Moreso, among the years several injections had been performed , with a regular interval of about five years, under the lock head and bottom. Each injection showed the existence of large voids under the construction which showed that a major problem of soil erosion was the main cause of the rapid worsening of the state of the lock. The injections showed not to be appropriate to stop this proces of erosion and only were a means of temporarily stabilising the structure.

2 SOIL CONDITIONS

In figure 1 in annex a layout of the site is given. The lock under consideration is the middle lock. The soil investigation consisted of :

- CPT tests around the complex and in boreholes through the construction. Special measures had to be taken to perform CPT tests through the bottom slab because of the high waterpressure under the slab. In total 9 CPT tests have been performed through the bottom of the lock.
- Sampling of the soil under the lock with MOSTAP apparates, operated by means of CPT equipment. Tree MOSTAP borings have been executed.
- Installation of a grid of open tubes to monitor head levels. 3 piezometers have been installed underneath the lock bottom, 3 under the lock walls and 10 piezometers in the area around the lock. With this piezometers the piezometric level has been controlled during all operations.
- laboratory tests on the samples, seevings and permeability tests

In figure 2 (top right) a representative CPT is given performed near the bottom of the lock. Figure 2 (lower half) also shows a representative seeving curve of the material under the lock. It could be concluded that the lock was built on heavy compacted sands showing cone resistances up to 20 Mpa.

3 GROUNDWATERFLOW AND POREWATERPRESSURE HEADS

A clear view on the groundwaterflow conditions and pressure heads was of utmost importance to understand the mechanism of erosion under the locks and to design appropriate remediation works. The grid of piezometers was monitored during a period of a few months. As a reference, the water head levels were measured on Monday mornings before the locks started to operate. The influence of the changing waterlevels in the locks when in operation was also studied. Even during the works and up to now, the piezometers are monitored weekly and allow to see the effects of the measures taken.

The steady-state situation was modelled by means of the groundwaterflow software package SEEP/W. A plan view 2D approach checked by lateral and perpendicular 2D cross section check calculations was found to be appropriate in this situation. Through fine tuning of the boundary conditions and of the hydraulic permeability of the relevant soil layers, the at rest situation could be verified. The measured and calculated heads matched well. See paragraph 6 for a plot of the calculates head contours.

4 PROBLEM DEFINITION

When studying the porewaterpressure heads it became clear that under the upward half of the middle lock, which was under consideration because severe deformations were observed, the head levels were as high as +11.5 m (referred to datum). The lower waterlevel in the lock is only +9.7 m and the slab has a thikness of about 1.6 m. This means that, due to the head difference of 1.8 m, the gradient of the waterflow though the cracks in the slab is larger than the critical gradient. When the cracks are large enough, soil particles of the sandy foundation layer can be transported inward the lock. The transport of sand could be observed when the lock was dry for the remediation works. The head difference was of course even larger and sand heaps were formed at the largest cracks.

The massive concrete structure of the lock, build in the thirties, shows many fissures and cracks, not only in the bottom slab but also in the bottom and the walls of the galeries alongside of the lock, used for filling and emptying. These fissures and cracks are caused by temperature effects and deformation of the construction when in operation. The part of the lock that shows the most severe deformations was reported to have had damage from bombings at the end of World-War II.

Because of the soil transport also from underneath the walls of the lock, these walls show large deformations (settlements an tilting). The stability of the walls was verified and it was found that the necessary safety could not be guarantied.

5 REMEDIATION BY DEWATERING WELLS COMBINED WITH VHP JET GROUTING

From the problem analysis it is clear that simple grouting under the bottom slab and under the walls cannot give a solution on long term. Since the cracks still exist and re-open after a period of operation, the erosion will start again. It was also considered impossible to close all the cracks in this old construction without rebuilding the lock totally. Therefore another solution had to be found to lower the waterpressure head under the lock. As a second problem, the stability of the walls of the lock had to be assured. Following remediation techniques were proposed: The lock gate bottom was structurally repaired to fix the biggest cracks and holes. In addition, relief wells were constructed through the lock bottom to lower the water pressure under the construction. To prevent very high water loss through these wells a new and important cutt-off screen was constructed under the upper head of the lock to cut-off the water flow from the upper canal section.

The relief wells which are constructed with a dewatering pipe system that brings the groundwaterlevel lower to the level of the lower canal section by means of gravitational flow (no pumps) take away the 10 m water level difference which caused the serious soil erosion under the lock bottom. A little water level difference remained due to friction loss in the pipes and wells, but this little pressure was no longer able to cause soil erosion. Combined with the structural repair of the lock bottom and walls a lasting solution for the lock stability was created.

The cutt-off screen was executed by means of VHP jet grouting piles put close to eachother such that a complete grout wall was created in the subsoil under the lock head. With the same technique, a new and stable foundation was created under the lock walls to stabilise the movements towards the lock gate. Inside the piles and through the total height of the lock walls steel bar tendons were placed. These tendons were presterssed to totaly immobilise the wall structure and movement and to solidarise the complet lock wall construction with its new foundation.

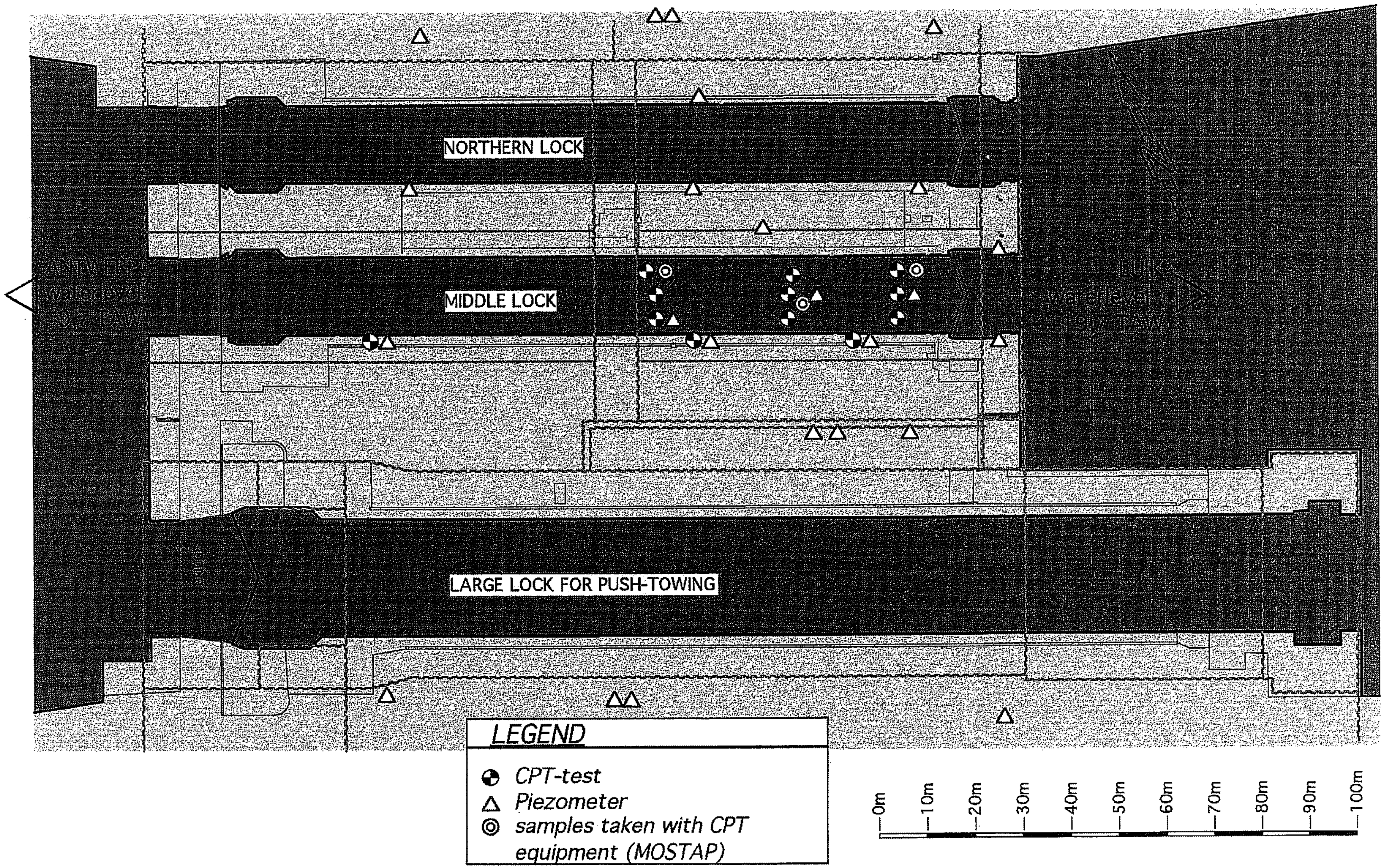
6 DESIGN OF THE RELIEF WELL SYSTEM

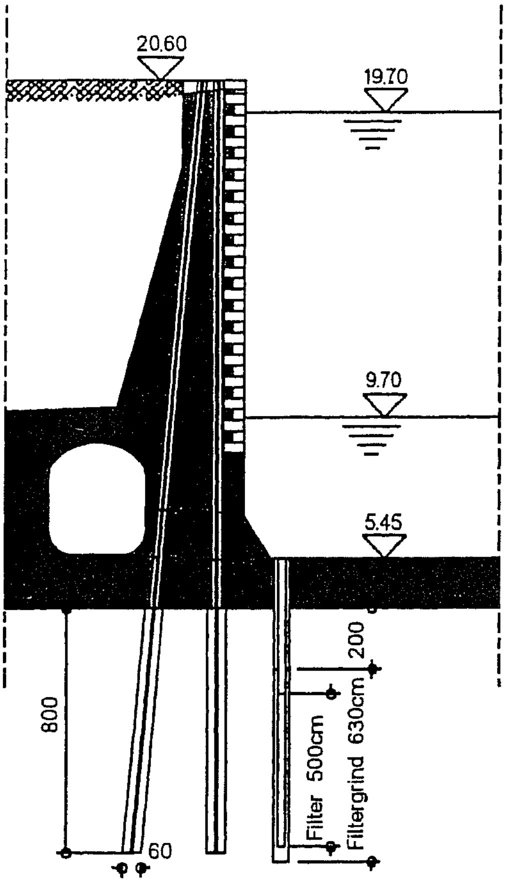
6.1 *Calculation of the expected flow*

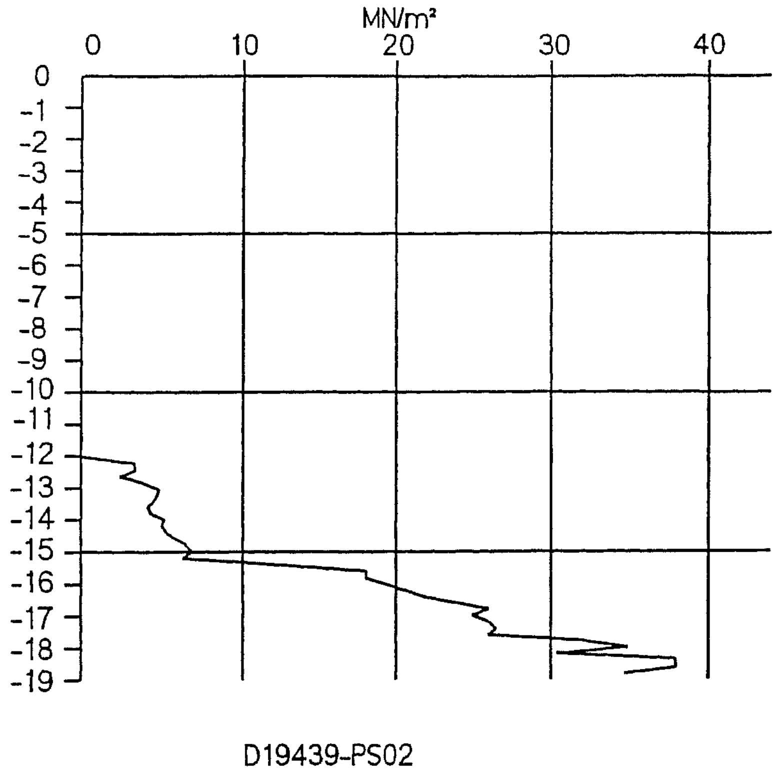
Due to the importance of a correct estimation of the amount of water to be drained by the wells a groundwaterflow model was made of the entire lock complex.

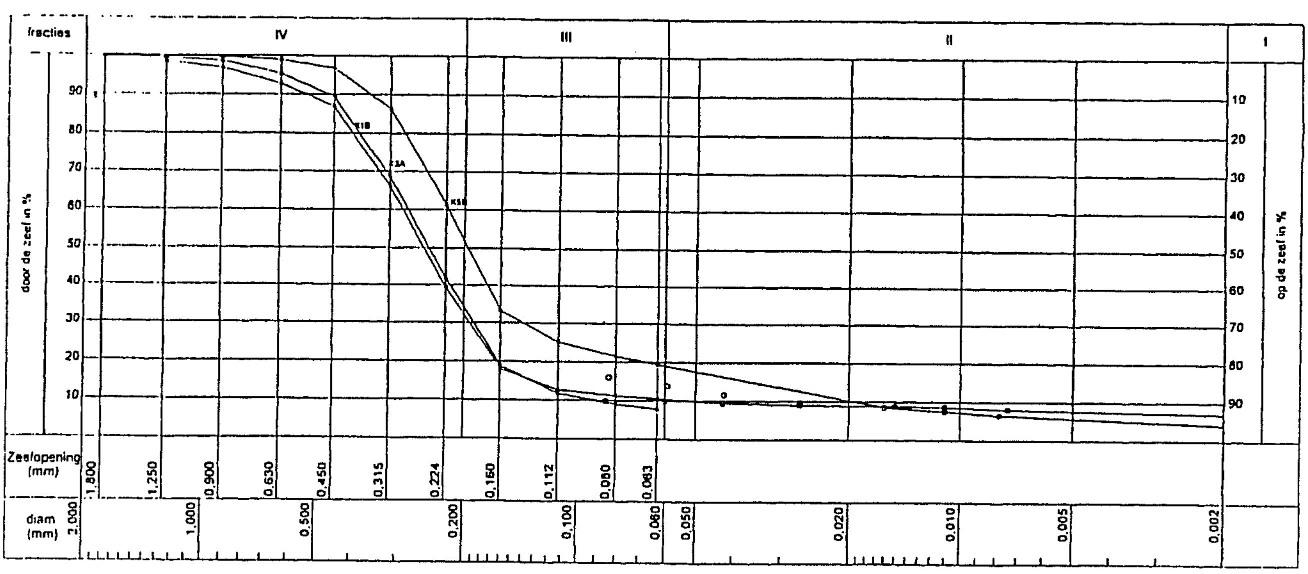
Based on the results of the calculated ground water flow and relief well debits the best geometrical placement of the wells was designed to realise an even drop in hydraulic head under the lock with comparable flow through every well.

LOCK SITUATION OLEN









6.2 *Construction of the wells*

Regarding the low-mainenance and the difficulties in repair the relief wells were designed such that a minimal risk of damage is possible. For this reason the wells are cast in in the concrete bottom of the lock and connected with cast-in pipes to drain away the water flow to the lower canal section.

The relief well system is completely shielded from polluted or sandy water and is only in contact with groundwaterflow. The filters and the complete drain system remain submerged all the time. This way the pies cannot collate.

7 MEASUREMENTS OF SOIL WATER LEVEL AND FOLLOW-UP

Due to the importance of a correct estimation of the amount of water to be drained away by the relief wells a large scale measurement campaign of the soil water level arround the lock complex was started. This was neccessary to be able to set up a realistic model of the soil water flow in the present and future situation.

When drilling the relief wells a follow up of the soil water level in the neighbourhood was performed and when the relief wells were connected to the dewatering tubes the sinking of the soil water level and the flow af water was measured and compared with calculations. The calculated situation appeared to be in good comparison with the measured data.

8 CONCLUSIONS

With the relief wells now fully operational we can state that the soil water level is stabilised and following expectations.

The solution was succesful thanks to the important investement in monitoring and measurement, combined with computer groundwater modelling. The combination of model with reality forms the best base for realistic predictions of groundwaterflow alterations.

The reduction of the water pressure under the lock prevents further soil erosion. This way, a long lasting, stable situation is achieved for the lock gate.

Because of the gravitational flow and the “cast-in” design of the relief wells, the wells don’t need maintenance and are able to reduce the water pressure for unlimited amount of time.

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