Recent developments in the application of HDPE vertical barrier systems in The Netherlands

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ABSTRACT

In the last two years, several large infrastructure projects were successfully constructed in the Netherlands with the use of HDPE vertical barriers. The executed schemes used HDPE panels made of 2mm thick HDPE liner welded to patented HDPE Geolock profiles. The panels have a width of 2.5 meter and lengths ranging from 8 meter to 26 meter. During the installation, a hydrophilic swelling cord is incorporated into the locks to create a complete seal. This article describes the application of the HDPE barrier on six different projects. It includes the design aspects, installation methods as well as laboratory measurements with regards to the durability of the material used, water tightness of the system and swelling capacity of the swelling cord when used in salt water. In the projects described, the barriers were used to prevent horizontal flow of water. On the projects the panels were installed by different contractors using equipment supplied by the manufacturer of the HDPE screens. In four projects (three near the city of Leeuwarden and one at the N381), the screens were used in the construction of aqueducts and underpasses. The screens were installed on these projects with a special installation plate in narrow trenches, made using partial predrilling and displacement, as well as in 'mixed-in-place' walls up to a depth of 18 meters. Near Nijmegen the screens were used in a river widening project to prevent the flow of water to the low lying land during high river discharges. The panels were installed using a reclaimable weight down to a depth of 26m in a 'cement-bentonite' trench made by a diaphragm wall grab. In a project near Rotterdam the panels were also installed in a diaphragm wall. They were installed to prevent ground water inflow into a long low lying section of a new highway.

Keywords: vertical barrier system, HDPE, geolock, cut off wall.

1 INTRODUCTION

This paper describes the use of a HDPE barrier system at several projects constructed in The Netherlands over the last two years. The barriers were installed by various contractors with equipment supplied by Cofra, the manufacturer of the HDPE barrier system. In all described projects the function of the barrier system is to obstruct a non-contaminated flow of water and allows for, in most cases, a polder to be constructed. In these polders a local lower water table was created with in the end a surface elevation below the outside water table. Figure 1 gives a map of the Netherlands and the locations of the projects.

2 THE BARRIER SYSTEM

The used barrier system consists of 2.5m wide 2mm thick HDPE panels with a special 4mm thick patented Geolock HDPE lock profile. The two parts, the female and the male profile, are welded to the two vertical sides of each 2.5m wide HDPE panel. A neoprene based rubber with very high chemical resistance is used to seal the lock construction.

Fig. 1. Geological map of the Netherlands. Numbers indicate the references for the described project locations (modified after Atlas van Nederland, deel 13: Geologie, 1985).

The strength of the connected profiles is higher than the strength of the liner and potential high stresses and deformations, which might occur after installation, can be accommodated for.

Figure 2 gives a cross section of the lock construction including a swollen neoprene based rubber swelling cord. The expansion of the swelling cord, together with the shape of the lock, creates a watertight barrier with high resistance against pressure.

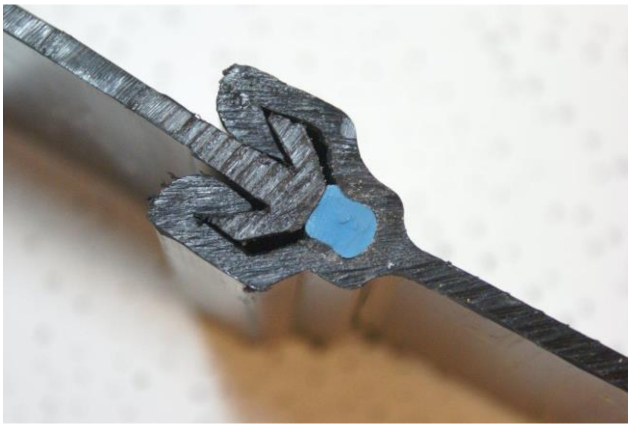

Fig. 2. Lock with Hydrotite swelling cord in swollen condition.

Research has been performed by KIWA institute (Erkel, 2014) to investigate the swelling behavior of the neoprene based rubber in groundwater and in saltwater conditions. The research has shown that for fresh water the final, non-confined, swelling percentage is 560% while for salt water this is less and ends at 350%. The swelling of the cord starts directly after submerging with a volumetric increase of 40% after 24 hours for both water types. When tested inside the locks a fast reduction in flow through the lock is measured. After 300 hours, a full closure of the lock is obtained. When considering the swelling behavior after 300 hours and comparing this to the unconfined conditions, a more or less 250% expansion of the cord is obtained for both water types at the time of closure. After the closure the pressure difference over the locks was gradually increased up to a pressure difference of 300 kPa (30m water). Figure 3 gives a graph of flow measurements taken during the measurement series.

The measurements show that the lock remains watertight at large pressure differences. During some of the pressure steps a flow of water was observed through the locks. This water flow quickly reduced to non-measurable values. It can therefore be concluded that when flow paths occur due to movement or pressure differences, the neoprene based rubber is capable to close new flow paths by additional swelling capacity and guarantees a complete seal of the system.

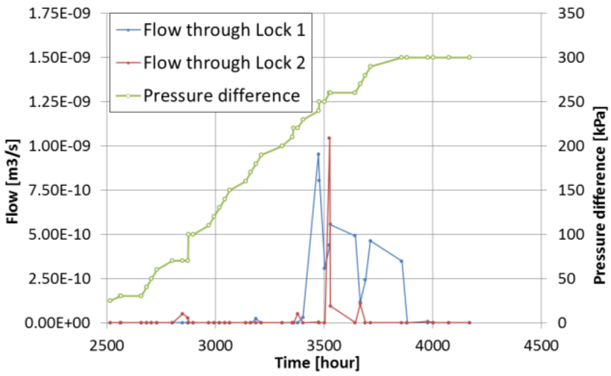

Fig. 3. Flow through 1.25m long lock sections in time with increasing pressures.

The long term flow rate through the connected profiles was subsequently determined by a long term test, measuring the flow of water through a 1.25m section of lock profile under a 10kPa water pressure. The measurements of the loss of water lead to a very low long term flow rate of 1m high section of a 2.5m wide panel of in average $1.7*10^{-18}$ m^3/s. Figure 4 shows the actual measurements of the water flow after the complete seal has been established.

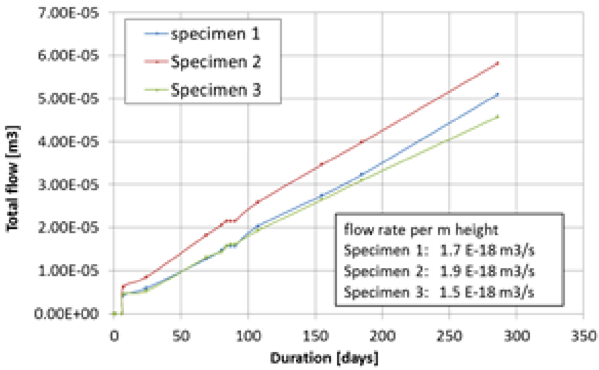

Fig. 4. Long term measurements of the water flow through three 1.25m long lock sections after complete seal.

The durability of the system was investigated by TNO (Langeveld 2013) using a 3000 hour exposure test in a 100 degrees oven, equivalent to a 100 year lifetime under temperatures lower than 20 degrees Celsius. It was concluded that the strength of the used materials did not degrade after the test and even increased by 10%. The thermo-oxidation times of the materials, as per ASTM D3895, reduced from initial values of 105/145 (profile material/ liner material) minutes to 72/85 minutes after 3000 hours. This is far higher than the required 20 minutes. The welds were also tested per ASTM D5397 and provide enough resistance against rupture during the 100 years reviewed. The system has therefore a life expectancy of over 100 years.

3 INSTALLATION

The 2.5m wide HDPE panels are installed into a trench using a retractable weight or guiding plate equipped with a special release mechanism. The lock profiles are used to interconnect the panels and guide the panel during the installation to the correct position in order to form a continuous barrier. Quality assurance is in place to monitor the connection of the profiles throughout the installation depth.

The installation trench can be made using a trencher, a diaphragm wall grab or a partial predrilling and displacement method. The method to be used is selected after an interpretation of the local soil conditions, depth of installation and project conditions. All trenches are filled with a bentonite, a cement-bentonite or a soil-bentonite mixture to assure the stability of the trench. Figure 5 presents the installation procedure using a trencher.

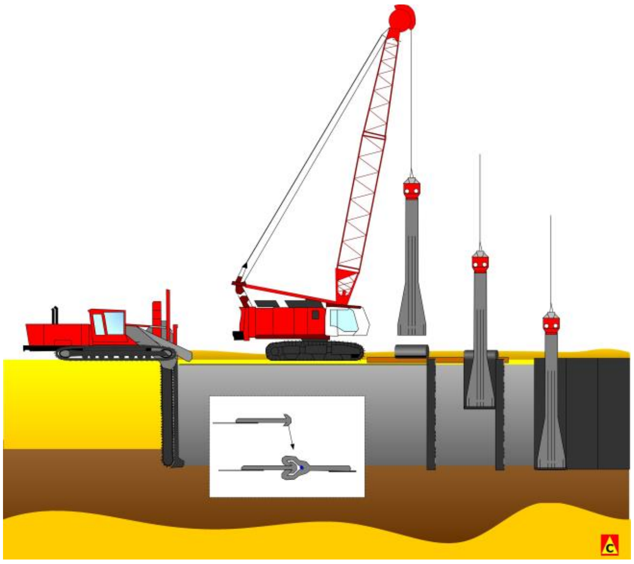

Fig. 5. Installation procedure of the barrier using a trencher.

4 PROJECT 1 - HAAK OM LEEUWARDEN

In the new bypass around the city of Leeuwarden, see project 1 in figure 1, three separate projects for three different main contractors were executed in 2013 and 2014 using the HDPE barrier system. The location of the various barrier sections in the projects is shown in figure 6. In the projects, the system was used in the construction of two aquaducts and three underpasses underneath a railway line.

The system was combined with and connected to sheet pile walls and cement-bentonite diaphragm walls to create a barrier against the surrounding water. The total wall surface of the HDPE barrier in the combined projects was 20.000m^2.

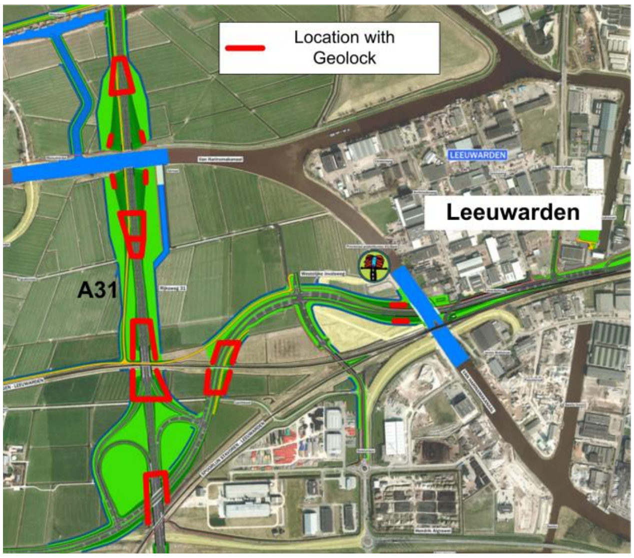

Fig. 6. Location of the HDPE barriers (modified from http://www.vrij-baan.nl).

The panels were installed through the Holocene clay and sand layers into a low permeable glacial clay layer at a depth of 8 to 18 meter below the surface. This was sufficient to limit the inflow of water from the surrounding area into the low lying underpasses.

In each of the projects different methods were used to make the trench. For these projects this was mainly related to the design and execution method chosen by the designer and the depth of installation. The panels were successfully installed into a mixed-in-place wall, a cement-bentonite diaphragm wall and a partial predrilling replacement wall. Near the underpasses the panels were connected to steel sheet piles using special connections to guarantee a watertight connection. Figure 7 gives an image of the installation into the diaphragm wall.

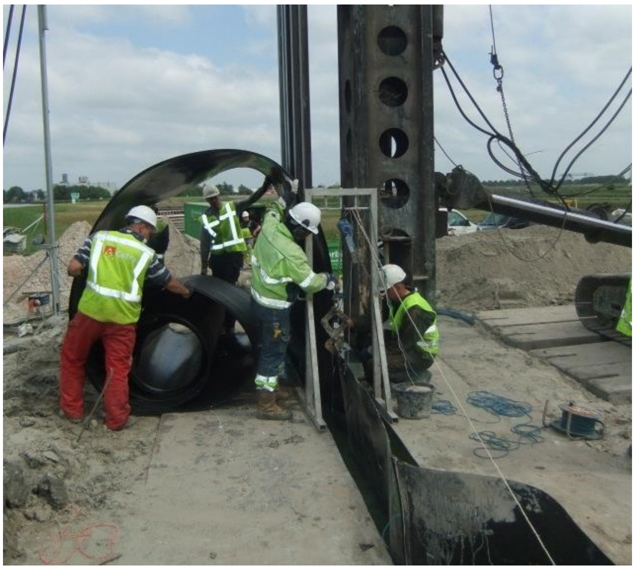

Fig. 7. Installation of the panel in partially hardened diaphragm wall (www.bam.nl).

5 PROJECT 2 - N381

The provincial road between Drachten and Assen is reconstructed to make the road safer, accommodate for the increasing traffic and bypass several villages. Project 2 in Figure 1 shows the location of the project. In the project four underpasses were constructed using the barrier system with a total wall surface of 13.750m^2. The depth of the panels varied between 2.5m, to obstruct surface water inflow to 16.7m, to create a complete watertight barrier. All sections were installed using the partial predrilling and replacement method with the bottom of the panels, for the deeper sections, installed into the glacial clay.

During the excavation of the trench boulders were encountered in the glacial clay at the location of the barrier. As the boulders were too big to be removed, the path of the barrier was slightly adjusted in 2.5m sections. This was relatively simple due to the flexible nature of the panels. The panels can be bent making it possible to install the panels around objects. Figure 8 shows a picture of the installation.

Fig. 8. Installation of a panel on the N381.

6 PROJECT 3 - A4

The third project involves the installation of the HDPE barrier in a stretch of a new highway between The Hague and Rotterdam, see project 3 in Figure 1. A 2.5km long section of the highway is, due to landscape and environmental reasons, constructed below ground surface and ground water level. During a detailed analysis of the initial design solution, a cement bentonite diaphragm wall of 0.4m thickness, it came forward that additional measures were required to guarantee the water tightness. The movement of the wall in the very soft peat deposits during the excavation of the highway and construction sequences would cause cracks in the wall and potential leakage paths for the water. It was therefore decided to incorporate the HDPE barrier into the cement-bentonite wall. Figure 9 shows the HDPE panels and the wall

Fig. 9. The wall after installation and excavation of the installation berm.

A large number of panels, with a total surface area of 40.000m^2, were delivered to the two contractors installing the diaphragm wall. As the trench was free of soil, a weight, supplied by the manufacturer of the panels, was used to bring the panels to the required depth. Figure 10 shows the retractable installation weight.

Fig. 10. Weight used for the installation of the panels top.

7 PROJECT 4 - LENT

The last project discussed is located near Nijmegen, see project 4 in figure 1, and part of a large flood protection plan in The Netherlands. On the location of the project an additional channel is dug for the river Waal to allow for a higher discharge capacity of the river in times of high water. The HDPE barrier was installed inside a 19m, max 26m, deep and 1.5km long cement-bentonite wall located underneath a 7.5m L-shaped retaining wall, see figure 11.

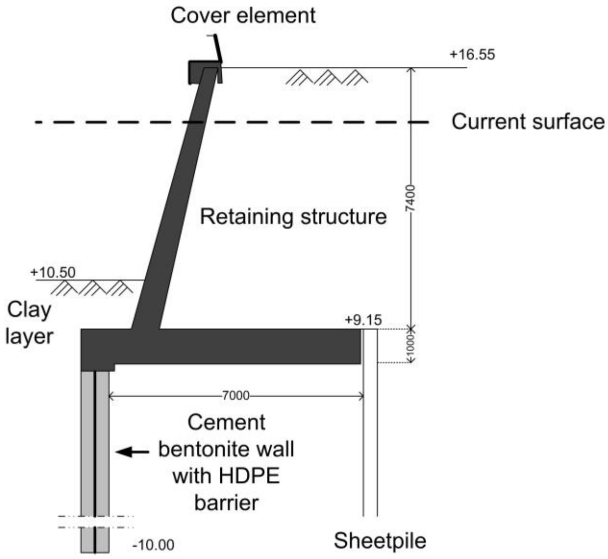

Fig. 11. Structure of the retaining wall (after Effing, 2014).

With a height difference of about 14 meters between the bottom of the new channel and the top of the retaining structure a leakage protection system was required to prevent any water progressing towards the city of Lent.

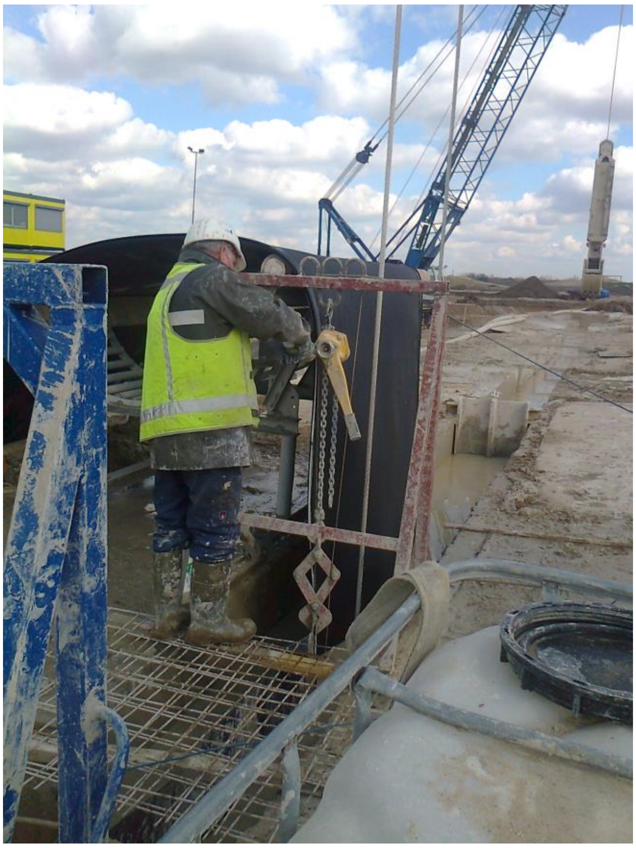

Fig. 12. Installation of the HDPE screen in the cement-bentonite wall.

In the initial design a steel sheet pile wall was specified to guarantee the water tightness of the wall. In the tender design of the contractor, this sheet pile wall was, due to economic reasons, replaced by a HDPE barrier. A picture of the installation is given in figure 12.

8 CONCLUSION

In the last two years, a large number of projects were constructed in The Netherlands using a HDPE barrier system with special locking system and hydrophilic swelling cord. The barrier system was, in all projects, used for the obstruction of water flow. Installation depths varied between a minimal depth of 2.5 meters up to a depth of 26 meters below the surface. Various installation tools, from installation using partial predrilling and installation of the panels with a guiding plate up to installation in a cement bentonite trench made using diaphragm wall grab and a drop weight to lower the panels, were used to successfully complete the projects.

The used hydrophilic cord has sufficient swelling capacity to completely block the potential leakage paths, even in salt water conditions. Laboratory tests have shown that the lock is watertight with a leakage over a 1m high section of in average 1.7*10-18 m^3/s. Upon changes in pressure some rearrangement could occur within the lock resulting a short period of higher flow. After only a short period of time, the leakage is stopped due to additional swelling of the cord. Tests as per ASTM standards, have shown that the materials used have a lifetime longer than 100 years.

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