LANDFILL ‘SCHOTEROOG’ BY MEANS OF A CEMENT-BENTONITE-LINER COMPOSITE WALL

Introduction

Through environmental rehabilitation of the landfill Schoteroog in Haarlem, the Netherlands, the geo-hydrological isolation of this former waste dump is realised by means of a cement-bentonite-liner composite wall. A team of COFRA B.V. and Fundamentum B.V. was retained by the Province of North Holland to provide an adequate cut-off barrier.
Therefore, around this landfill area, a 120 mm thick cement-bentonite wall is constructed, in which an HDPE liner is vertically installed. This type of composite wall combines a minimal permeability with a high mechanical resistance and long service lifetime. Like vertical sheet-piled barriers, the lining wall consists of panels, which are interlocked by means of welded-on lock profiles. At the Schoteroog landfill a measuring system is conducted to monitor the permeability of the locks in-situ. This paper gives a short overview of above mentioned project, the application and construction of the composite wall and the results of the permeability measurements of the locks.

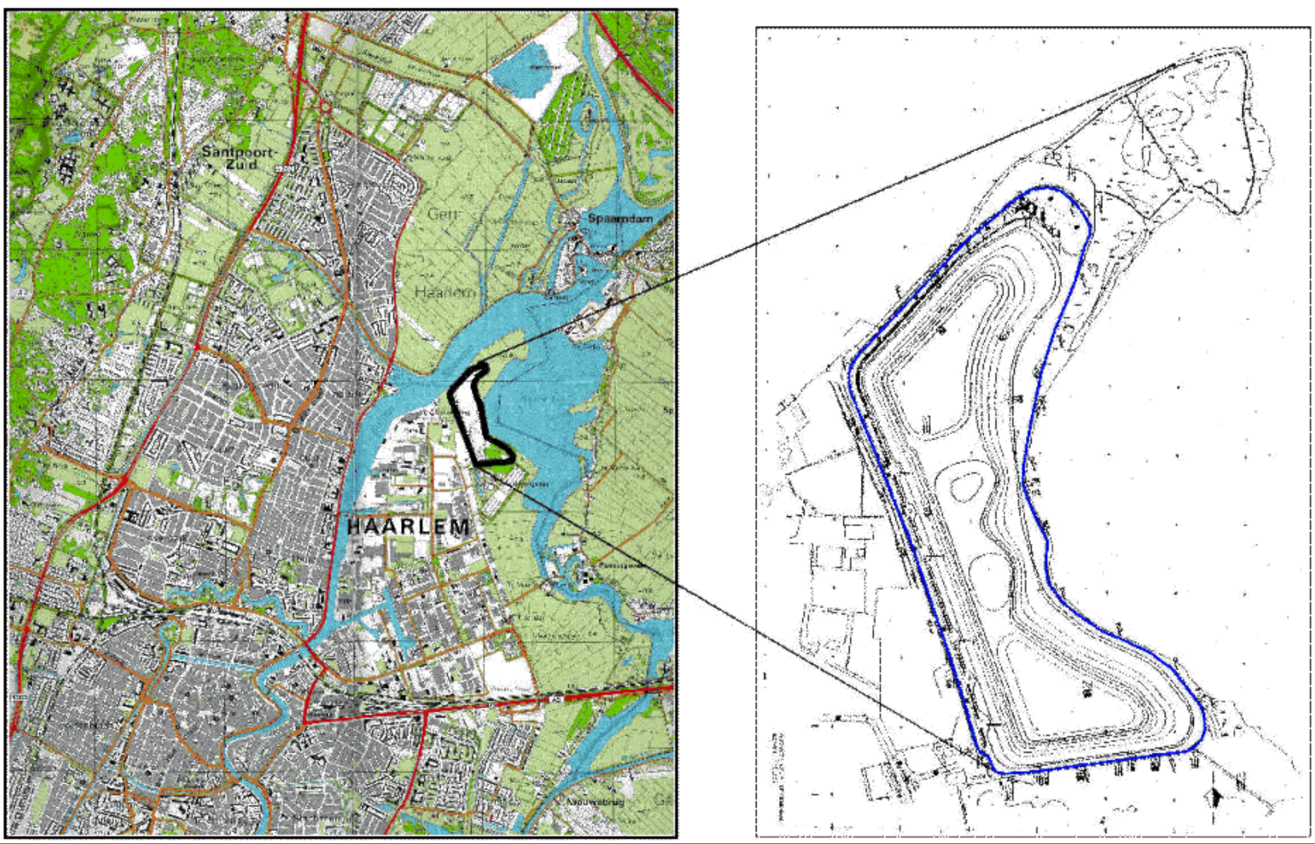


Figure 1

Rehabilitation of the Schoteroog landfill

Between 1971 and 1977 the landfill Schoteroog (Fig. 1) was used to dump municipal and industrial waste and rubble materials. Thereafter, the Province of North Holland has temporarily determined Schoteroog as waste dump once again. Over a period of 1.5 year approx. 450,000 m³ of waste materials was dumped. For re-opening the dump site, the soil mechanics institute OMEGAM (Onderzoeksdienst voor Milieu and Grondmechanica Amsterdam) conducted a detail soil investigation research, from which was concluded that the site should be rehabilitate according to the so-called IBC-basis, referring to a method of Isolation, Check and Control.
Based on the results of such report, the Province of North Holland conducted an appropriate rehabilita-

tion program, major part of which consists of controlling the contamination of the ground water.
Significant part of the landfill is cut-off the open water locations Noorder Buiten Spaarne and Mooie Nel.
Furthermore, at its south western side, a water treatment plant (RWZI) extract ground water from the site.
The landfill is an area with a relative lower water table in the deeper sand layers and ground water extraction by the RWZI causes a flow of contaminated ground water from the waste dump towards the water treatment plant. Therefore, the rehabilitation program should cover for a geo-hydrological isolation.
This construction consists of following parts:

- a cut-off wall surrounding the landfill
- an upper seal isolation technique
- 21 extraction filters (wells).

By means of lowering the ground water level within the barrier, a ground water flow towards the landfill is created. Accordingly, such wall considerably restricts the impact of the ground water level outside, on the ground water level inside the landfill, thus reducing migration of contamination from other locations.
Moreover, the quantity of percolate to be cleansed is reduced. From MICROFEM model calculations results that up to 5 times less percolate is to be derived in the exploitation stadium, in comparison with lowering the water table level without application of a barrier wall. Finally, such results into a factor 7 through accomplishing the upper seal construction.
According the calculations, a flow of 100 m³ to 125 m3 per day is predicted for the control phase, in applying 21 wells and a head of 1 meter.

Various cut-off composite walls

Construction of vertical cut-off barriers can be realised using various methods. Adequate application and construction of such walls are subject to following specifications and criteria:

- minimal length
- maximal water tightness
- chemical resistance
- service lifetime
- commercial feasibility
- constructive characteristics of the wall (deformation under pressure)
- maximum weight of material of other limiting factors (obstacles in the subsoil).

For various types of sheet-piled walls, above mentioned requirements are shown in table 1.

TABLE 1

E = Excellent G = Good F = Fair S = Satisfactory P = Poor ?* = Leakage at lock ?** = Underseepage	Obstacles	Chemical resistance	Life	Nuisance	Mobilisation (weeks)	Depth (m)	k-Value (10^{-8} m/s)	Thickness (mm)
Steel sheet piled wall (heavy)	G	S	S	P	1	20	?*	10
Steel sheet piled wall (light)	P	S	P	G	1	10	?*	2
Bentonite wall	F	E	F	F	2	25	10	100
Injection-moulded film wall	P	E	E	F	2	15	?*	2
- GEOLOCK -	P	E	E	E	1	25	0.00001	4
Moulded film wall	G	E	E	F	1	5	?**	1
Excavated bentonite wall	E	G	G	F	4	70	1	600
Bentonite / GEOLOCK wall	E	E	E	F	4	50	0.0001	100

GEOLOCK

GEOLOCK is a high-quality sheet-pile wall system, in which HDPE panels are interlocked by means of welded-on HDPE lock profiles. This flexible, chemically resistant material possesses excellent stress-crack resistance and a very long service life. The highly adaptable material, combined with the well designed interlocks, allowing for installation to depths up to 40m, makes GEOLOCK an ideal vertical cut-off wall.
In table 1, two GEOLOCK applications are shown. When using GEOLOCK as a lining barrier in compressible soil, without sharp obstacles, the individual HDPE liner is a sufficient vertical cut-off wall. The construction of the barrier wall is accomplished using a vibration rig or through a jetting method.
Application of GEOLOCK in combination with a cement-bentonite wall is highly resistant against obstacles in, and deformation of the subsoil. The cement-bentonite-liner wall results into the lowest possible permeability characteristics.
Table 2 shows the various GEOLOCK systems and its permeability factors. Measurements are based on 1m STIJGHOOGTE difference.

TABLE 2 GEOLOCK screens of 2m width, for 1m STIJGHOOGTE difference at the wall, based on laboratory examinations

	Thickness (mm)	k-value (m/s)	Flow l/m²/year
Geolock Jetted	2	10^{-12}	1.8
Bentonite/ Cement	800	10^{-12}	10.8
Geolock in Bentonite	100	10^{-12}	0.3

In the GEOLOCK sheet-piled wall system, HDPE panels are connected through interlock profiles, in which groove a watertight expansion seal, Hydrotite, is used to ensure a watertight construction. Hydrotite is a neoprene based rubber material with a high chemical resistance that can swell up to 16 times its original volume, thus eliminating the permeability of the locks. The material specifications of GEOLOCK are given in table 3.
The lock sections provided with Hydrotite expansion profile are shown in Fig. 2. The locks (1,3) are welded onto the liner (2). The tensile strength of the lock section exceeds that of the liner material itself, consequently maintaining the water tightness of the construction, even in a highly deformed condition.
The permeability of the 120 mm thick cement-bentonite GEOLOCK wall, measured in flow/m²/year, is a factor 36 lower than the permeability of a cement-bentonite wall executed without liner.

TABLE 3 Specifications of Geolock panels

Panel width	0.5 – 5 m
Length	2 mm
Thickness	4 – 30 m
Weight	2 kg/m²
Tensile strength liner	34 kN/m
Tensile strength lock	50 kN/m
Permeability of lock	3.5 l/year/m at 10 kPa
Elongation at break	18%
Elasticity coefficient	800 N/mm²

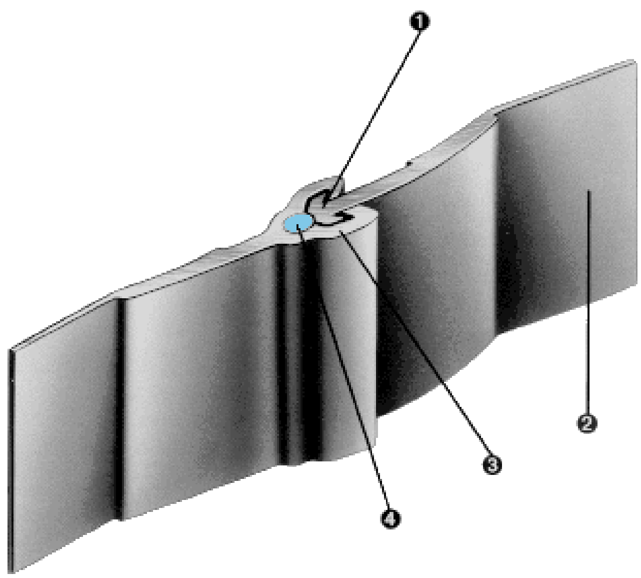


Figure 2 Lock construction

In applying the GEOLOCK system extensive experience is generated. Applications refer to:

- hydraulic isolation of contamination
- restriction of ground water leakage through i.e. dikes
- isolation of gasses in waste depots.

As a consequence of its unique characteristics, a GEOLOCK bentonite-cement cut-off wall was chosen to be installed around the Schoteroog landfill.

Cement-bentonite GEOLOCK wall Schoteroog

The subsoil under the landfill exists until a depth of approx. – 3 m of a sandy layer situated on top of a 1-1.5 m thick peat layer. Under this layer are permeable sand layers and some shell banks. On approx. –11 m to –12 m exists a sandy clay layer that acts in the geohydraulic isolation as an aquitard.

The contract described following requirements:

1. Vertical cut-off wall into the aquitard.
2. Wall thickness > 120 mm.
3. Permeability < 10^{-9} m/s.

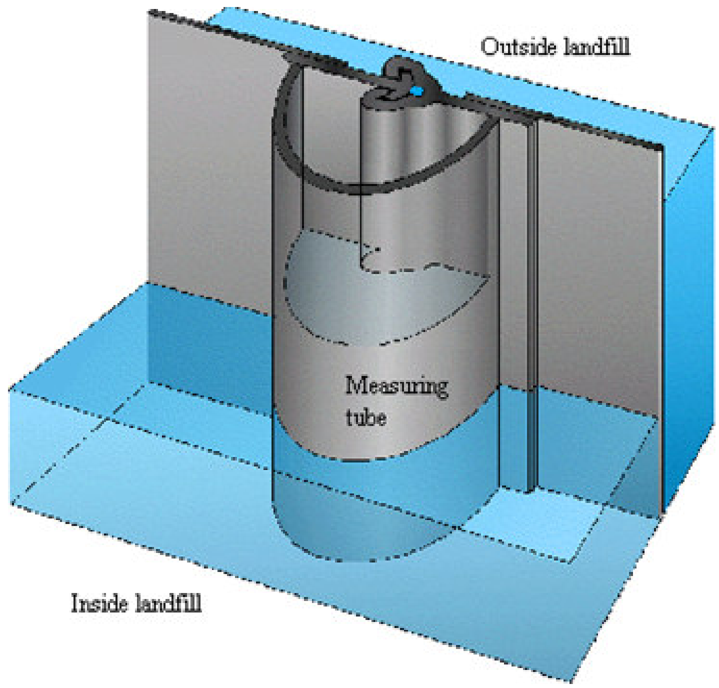
During the installation off the cut-off wall following difficulties were found:

- Over-consumption of the cement-bentonite mixture caused by flow of the mixture in the sand layers and shell banks.
- Instability off the wall in the sand layers caused by liquifaction of the sand layers due to the vibration technique used to install the panels.

The sand layers are characterised by a high penetration resistance and a very small variation on particle size. This DUID OP a very dense sand that is therefor very sensible to liquefaction. Also the Dutch cone penetration tests which were made before and after construction of the wall did not show any significant change in resistance. This confirms the high relative density of the sand layers.
After adjustment of the composition of the bentonite-cement mixture it was possible to install the wall to the required depth. The total length off the cut-off wall is approx. 2.415 m and with the 1180 installed panels a wall with a total area off 29.103 m² is constructed. The average length of the panels is 12.1 m, which results in a total of 14,278 m lock.

In-situ measurements of the GEOLOCK panel connections.

To determine the permeability of the installed panels, a measuring system is connected to a number of locks. To create the geo-hydrological isolation, the groundwater table inside the wall is lowered with 1 m till –1.6 N.AP. This creates a situation whereby the flow of groundwater is always in he direction of the landfill
Outside the cut-off wall the groundwater table is approx. N.A.P. –0.60 m till –0.80 m. to measure the flow through the lock is on the inside a half HDPE tube welded to the lock in the middle of a panel. In the tube the water level can be measured



To measure the flow through the lock, a half HDPE tube is welded to the lock at the inside of the cut-off wall. In the tube the change water level during a certain period can be measured and compared with the ground water table outside the cut-off wall. From these measurements and the length of the lock in the tube the flow can be calculated.

From the lock measuring system an average leakage of 3.21 cm³/day per meter lock at 1 m head was found. For the total cut-off wall this mean 46 liter per day.

In the period during which the lock leakage measurements were made, also the amounts discharged from the wells inside the landfill were monitored.
The total flow over the period from may 1996 till september 1996 was 17,742 m³, or 131 m³/day. The majority of this flow is leakage through the aquitard. The leakage through the locks during this period is only 6.6 m³. It is clear that this amount is negligible

The summer of 1996 was characterised by a shortage of precipitation. The precipitation during the measuring period was lower than the evaporation.
This means that the share of precipitation in the amount of discharged water is also negligible. The flow to the landfill during this period is only depending on the difference in groundwater tables inside and outside the cut-off wall en gives therewith a good indication of the expected flow during during the period when the landfill capping will be completed.

From the measurements the permeability of the cut-off wall can be calculated. Based on the wall thickness of 120 mm, a k-value of $3{,}6*10^{-12}$ m/s was calculated. This value is not only based on the flow through the locks but also the theoretical amount of water that flow through the HDPE-liner being 1,08 $cm^3/day/m^2$ at a head of 10 kPa is included. Herewith the requirements from the tender documents of $k < 10^{-9}$ m/s for a 120 mm thick wall is met.

Conclusions

To create a geo-hydrological isolation of the landfill Schoteroog as part of the renovation of a recreational area in the province of Noord-Holland, a cement-bentonite Geolock wall was constructed.
From the in situ measurements it was determined that the permeability of the cut-off wall was much lower than the required permeability as described in the tender documents.
In the project Schoteroog the leakage of the cut-off wall is determined by an very effective lock measuring system which measurements correlated with theoretical values and flows found at the discharge systems.