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Geosynthetic clay liners for landfills in comparison with other mineral seals in relation to the Dutch legislation

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ABSTRACT: Up to now for the sealing of landfills in the Netherlands there is used a HDPE-membrane mostly in combination with a sand bentonite layer with a thickness of 0.2 to 0.5 m. For covers above landfills with a combination sealing - synthetic and mineral layer - it should be examined whether the mineral sealing has to be installed under or above the HDPE-membrane. Until now mostly the HDPE-geomembrane is applied above the mineral layer because of the necessary compaction of the mineral layer.
By using Geosynthetic Clay liners (GCL) better sealing results can be achieved. By using stronger geotextiles, better bentonite powder and a production with internal and external quality control, GCLs are better than or equal with soil and mix (SAM) or Compacted Clay Liners (CCL). It is especially better at relatively steep slopes and in combination with a HDPE-membrane. Namely there is a good interaction between geomembrane and GCL (intimate contact) and it is possible to install the GCL on top or under the geomembrane.

1. INTRODUCTION

In the last decade there have been many developments in the area of the sealing of landfills. Approximately ten years ago the first demands of the Ministry of Housing, Planning and Environment were made with regard to landfills without a base sealing, to provide them with a sealing that would be able to resist the infiltration of rainwater. In the course of years the demands have become more extensive. In the Netherlands a landfill has to have both a composite base and cap sealing. The capping of a landfill is made of a synthetic sealing, which consists of a 2 mm HDPE-geomembrane and a mineral sealing. Sand bentonite and clay are mentioned as a mineral layer in the directive [lit. 4 and 5]. Starting-point of the composite sealing is that the geomembrane is technical impermeable but has, under the influence of settlements and mechanical loads, only a limited life cycle. A mineral sealing is less sensitive for mechanical damage and also vulnerable against settlements.

It is reasonable to believe that a significant reduction of the leakage can be achieved with a composite sealing structure, made out of a synthetic and a mineral sealing layer, as anticipated [lit.4].

A mineral sealing layer has a good plasticity. Small crackings are closed by the swelling of the material. Because of this self-repairing ability, the anticipated life of a mineral sealing is considered to be longer in comparing to a synthetic sealing [lit. 4].

The effective permeability of both sealings separately is equal in the long term. By placing both layers in direct contact on top of each other, the total leakage can be reduced and, consequently, the risk of an inadmissible infiltration is reduced further [lit. 4]

Apart from sealings made of sand bentonite (SAM) and clay (CCL), GCLs have been developed a couple of years ago. These GCLs combine the advantages of a mineral sealing with the controlled quality of a premanufactured product. Additionally they can be applied independent of most weather conditions.

2. THE PREFABRICATED BENTONITE MAT (GCL)

2.1 *Different Types of GCLs*

GCLs were developed a number of years ago. At the moment there are three basic types of GCLs available in the market [lit. 1]:

a. Needle-punched GCLs

The bentonite is held in place between the carrier and cover geotextiles by means of needle punching. The geotextile on at least one side must be a needle-punched geotextile without a woven component. The needle-punching process transmits fibres from the non-woven through the bentonite layer and reinforces these fibres into the carrier geotextile, producing a fibre reinforced GCL with the bentonite embedded erosion stable. After hydration the GCL maintains a uniform thickness. The carrier geotextile can be nearly any other geosynthetic, such as a woven, a needle-punched geotextile or a combination of both. The bentonite can be either in powder or granular form.

b. Stitched GCLs

The bentonite is held in place between the carrier and cover geotextiles by means of parallel stitching. The spacing of the stitching can be varied. After hydration the GCL thickness is dependent upon the tightness of the stitching and the confining stress. The geotextile can be woven or non-woven. The bentonite can be either in powder of granular form.

c. Glued GCLs

The bentonite is fixed to the geotextile respective to the thin geomembrane by means of an adhesive. After hydration the GCL maintains a uniform thickness. Once hydrated the glue dissolves losing its adhesive nature. The bentonite is in a granular form.

2.2 *GCL Structure*

Following there will be an explanation in general of what the functions of the different parts of a GCL are.

2.2.1 The Bentonite Layer

The bentonite layer is there to act as a barrier to gas and liquids. The permeability, value k, indicates how effective a material is (in the case of GCLs, usually bentonite) as a barrier. Normally k-value is measured with water. Typical values of GCLs are below 5×10^{-11} m/s. Bentonite is a good barrier to most liquids and gases after it is hydrated with water. GCLs are manufactured with either granular or powdered bentonite. Tests on GCLs after series of wetting and drying or freeze and thaw cycles show that GCLs maintain their k-values.

2.2.2 The Geosynthetic Components.

The geosynthetic components have two major functions, namely to keep the bentonite layer erosion stable in place in its non-hydrated state (transportation, installation of the GCL and installation of the cover material), and to keep the bentonite erosion stable in place after hydration for the anticipated service life of the GCL.

Various manufacturers use different geosynthetics. The needle-punched geotextiles vary from 200 g/m^2 to 500 g/m^2 mass per unit area, and the wovens from a light gauze to 200 g/m^2 slit film ones. The raw materials can be either polypropylene (PP) or high-density polyethylene (HDPE). Combinations of woven and non-woven are also used. The geomembranes used in one of the glued type of GCL vary in thickness, e.g. 0.5 mm to 1.5 mm and in raw material - PVC, HDPE, etc.

The initially designed GCLs (in the eighties) have already been superseded by technology several times. In particular during the last two years, needle punched GCLs have dominated the market. Improvements are:

- shear resistant GCLs
- prefabricated overlaps (bentonite filled overlaps)
- improvement of permeability
- internal shear-strength improvement
- intimate contact.

2.3 *Permeability of water*

The permeability of a mineral sealing is determined in a laboratory or is calculated with a certain k-value in compliance with Darcy's Law. The permeabilities of GCLs are in the range of $10^{-11} : 10^{-12}$ m/s.

2.3.1 The Calculation Method according to Darcy

v	=	k.i
v	=	specific flow rate (m/s)
k	=	permeability coefficient (m/s)
i	=	potential gradient (-)

The potential gradient (i) depends on the thickness of the sealing layer and the complete water column, which is:

i	=	$\frac{(h1 - h2) + d}{d}$
h1	=	water tension above the sealing (m)
h2	=	water tension beneath the sealing (m)
d	=	thickness of the impermeable layer (m)

2.3.2 Rules

In the Netherlands is referred to the directive 'Dichte eindafwerking' (Impermeable End Sealing) [lit. 5]; section 11.1.7 'Doorlatendheidsonderzoek' (Permeable Research), in which is stated that the leakage must not exceed 20 mm/year.

In that same directive [lit. 5] the field conditions for design are determined at i = 5, during 200 days. These 200 days are based on a period of a precipitation excess. The i = 5 is likely resulting from the 'Staring Centrum' report 91 'Richtlijnen voor ontwerp en constructie van eindafwerkingen van afval- en reststofbergingen' (Directives for Drafting and Constructing End Sealings for Waste and Residue Storage) [lit. 6]. This report is based on a water level of +0,5 m above the sealing layer and -0.5 m water level underneath. With a structural thickness of the sealing layer of 0.25 m (e.g. SAM), it does actually result in the potential gradient of 5.

2.3.3 Practical Conditions

In 'Toepassing van bentonietmatten' (Application of GCLs) [lit. 2], is considered whether the above-mentioned 1.0 m water level (1 mbar) on the sealing is correct; this in connection with a comparison between sand bentonite and GCLs. The following is noticed with regard to this matter:

"The hight of the water column on a capping is defined as 0.5 m. Such an overpressure is not very likely. Instead of a water column of 0.5 m on a capping, a water column of 0.3 m (in accordance with the drainage draft requirement) is more likely. In particular on slopes the water column on the sealing will unlikely increase up to 0.5 m. Besides that, maintenance and repair of the sealing construction is possible and therefore the drainage can be kept functioning.

The pressure underneath a capping is defined as -0.50 mbar. This pressure can be regarded as a 'worst case' assumption at the present landfills. Dependent on the kind of waste, landfill gas is released due to the biological decomposition of organic waste. It results in an overpressure in the landfill substance at most of the open landfills or in already closed landfills. According to our present knowledge, the overpressure will exist for several decades. Therefore, a degassing system is installed in landfills. An underpressure with an average of 0.10 to 0.20 mbar is applied in the degassing systems. This underpressure decreases quickly outside the immediate range of influence of the gas sources or suction drains. Empirical figures learn that the influence of a degassing system is limited to 5 to 10% of the entire surface. In general, there are overpressures outside the immediate range of influence. Consequently, it is more realistic to assume that the pressure in a landfill amounts to 0 mbar, and therefore to take an underpressure of 0.50 mbar as a starting point.

Taking the previous question into consideration, the gradient for a mineral sealing of 0.25 m (SAM) amounts to 2.2. The gradient for a mineral sealing of 10 mm (GCL) amounts to approximately 30 under the described parameters. In order to live up to the leakage-demand of 20 mm/year maximally, the permeability (k-value) for a mineral sealing layer of 10 mm has to amount to maximally 4×10^{-11} m/s".

In the table in section 2.3.5 a comparison is made between a GCL of 0.01 m and a SAM with a thickness of 0.25 m. The text above shows that the total water column will more likely be 0.10 m than 0.40 m. That is why the table gives a review of the differences in annual leakage losses, based on 0.40 m maximally.

2.3.4 Permeability Bentofix

A GCL (with a thickness of 10 mm) has to have a permeability of less than 4×10^{-11} m/s. The 'Prüfamt für Grundbau Bodenmechanik und Felsmechanik' of the Technical Universe of Munich [lit. 7] has examined Bentofix and their conclusion is that the permeability k of this product, with a supposed thickness of 1 cm is less than 1×10^{-11} m/s.

As is noticed in 2.2, the direct contact with the adjacent synthetic sealing (geomembrane) is, of course, of the utmost importance. The permeability in the overlap area [a], the permeability after biaxial elongations due to settlements [b], the gas-permeability [c] as well as self sealing due to penetrations [d] are also important aspects for landfill capping applications

a] The 'Institut für Bodentechnik und Felsmechanik' of the University of Karlsruhe [lit. 10] tested the influence of the overlap on the permeability. Two results were measured at an overlap of 0.30 m. 2×10^{-11} m/s and 4×10^{-12} m/s respectively.

b]) In January 1994, the 'Institut für Grundbau, Bodenmechanik und Energiewasserbau' of the University of Hannover [lit. 11] examined the permeability of Bentofix, type BFG5000, in elongated condition. This research took place with regards to the fact that such a sealing must be able to follow settlements. The results ware as following:

Permeability k unelongated	$9{,}9 \times 10^{-12}$ m/s
Permeability k after 24 hours swelling time at 19.5% biaxal elongation	$2{,}7 \times 10^{-12}$ m/s
Permeability k after 24 hours swelling time under pre-load 19.5% biaxial elongation	$9{,}3 \times 10^{-12}$ m/s

c] The ingenieursgesellschaft Prf. Czurda und Partner mbH (ICP) [lit. 13] carried out a test to determine whether a moist GCL is impermeable with regard to methane and petrol vapours. The results show that practically speaking Bentofix is gastight once hydrated.

d] The 'Prüfamt für Grundbau, Bodenmechanik und Felsmechanik' of the Technical University of Munich [lit. 12] tested the permeability of Bentofix after perforations. Based on the measurement data it can be said that Bentofix is capable of self-sealing adequately after perforations up to 18 mm.

These were the results:

Perforated size	k-value
2 mm	8×10^{-12} m/s
5 mm	1×10^{-11} m/s
10 mm	1×10^{-11} m/s
18 mm	2×10^{-11} m/s

2.3.5

Comparison with a conventional SAM.

The table below indicates the difference between Bentofix and a SAM as a capping of 0,25 m., with regard to an annual (200 days) leakage loss. The calculation is based on a total water column up to 0,40 m. (see 2.3.3. practical conditions).

Type of sealing	Bentofix k-value 1×10^{-11} max. thickness 0.01 m	SAM k-value 2×10^{-10} max. thickness 0.25 m
h1 - h2	leakage loss	leakage loss
0.10 m	1.9 mm	4.8 mm
0.20 m	3.6 mm	6.2 mm
0.30 m	5.4 mm	7.6 mm
0.40 m	7.1 mm	9.0 mm

The table shows that the eventual annual leakage loss under practical conditions is far less than the stipulated 20 mm/year.

2.4 *Loads*

Below is indicated what the behaviour of a GCL is under certain circumstances.

2.4.1 Tensile forces

GCLs should not be subjected to excessive tensile forces, especially during installation. GCLs should not be used as reinforcement layers.

2.4.2 Static loads

The static loads from the materials above the GCL will be transmitted through the GCL to the sungrade below the GCL. Point loads are to be avoided, stone sizes should be smaller than 16 mm. The GCL interface with the material in contact with the GCL must be carefully investigated.

2.4.3 Bentonite erosions

Water flowing on top of the GCL can cause the bentonite to erode out the GCL. This is best counteracted by using GCLs with thick needle-punched geotextiles or using a very fine-grained material soil between the GCL and the flowing water.

2.4.4 Chemical attack

In certain fluids (e.g. high salt concentration water) the dry bentonite hardly hydrates. However, once the bentonite is hydrated by fresh water it act a barrier to fluids, including salt water. Under certain conditions an ionic exchange can take place. As long as the GCL is under a reasonable surcharge, the effect of this ionic exchange on the permeability is usually limited to a gain of about 10. The k value could change from say 1×10^{-11} m/s to 1×10^{-10} m/s. A reasonable surcharge could be 500 mm of soil or more.

Chemical attack can also take place on the geosynthetic element of the GCL. PPs can degrade in contact with oxidising acids. HDPE geosynthetics have currently the best chemical resistance of all presently used geosynthetic raw materials.

In addition can be noticed that literature research for CUR C93 [lit. 2] shows that it is regarded unnecessary to carry out further research regarding a comparison with other mineral sealings in this field.

2.4.5 Animal, Bacteria and Root Attack

Rodents find no nourishment in geosynthetics or bentonite. However, they can bite their way through GCLs if there is food behind the material and if they are hungry enough.

Bacteria attack has not been found in GCLs. There is no evidence that they effect the permeability whatsoever.

Root penetration of GCLs should be avoided. Although the bentonite seals against the roots that do penetrate the GCL, there is a chance that a flowthrough might be observed through dead roots.

All these potential problems can be decreased by increasing the soil layer thickness above the GCL to 600 mm minimally.

In [lit. 2 and 3] it is indicated that by making use of a sound structure for the complete capping construction, for instance by applying a well-compressed drainage layer or by applying a drainage mat or anti-root cover on top of the sealing, there is no risk of penetration of roots and/or small animals in the sealing construction.

2.4.6 Frost Effects

Tests carried out in the laboratory on needle-punched GCLs using powdered bentonite, showed that the repeated freezing of the GCL did not effect its long-term k-value.

2.4.7 Wetting/Drying Cycles

Laboratory tests on GCLs have shown that the long-term k-values of GCLs are not effected by repeated wetting and drying.

2.5 *Implementation*

2.5.1. Guidelines

All GCL manufacturers have guidelines for the installation of their material. However, subjects which effect the cost to the contractor should be specifically detailed in the specification, in order to avoid extra claims from the contractor.

2.5.2 Accuracy of subgrade

The more accurate the subgrade is, the better the performance. One manufacturer recommends that the subgrade should not vary more than 30 mm when measured over a distance of 4 m. Rutting should not occur during installation. The surface should be smooth.

2.5.3 Unrolling the GCL

The protective wrapping should only by removed immediately prior to installation. A heavy duty spreader bar (the rolls can weigh from 500 to 900 kg) is usually used to unroll the GCL rolls, so that the supporting straps do not rub and damage the edges of the GCL roll. If possible the roll should be unrolled with the rolls on the ground. This reduces any tensile forces on the GCL.

2.5.4 The cover soil

The material to be placed on top of the GCL should be installed immediately after the GCL is placed. It should be avoided that the GCL is exposed for a long time without the cover layer installed. The soil cover layer should be installed in a thickness of at least 300 mm. The soil should be installed in the direction of the overlap and not against it, avoiding the chance that the soil could open up an overlap.

2.5.5 GCL Roll Sizes

The GCLs presently on the market available are in standard widths from 3.50 m to 4.80 m. The lengths are approximately 30 m.

2.5.6 Installation on Slopes

The maximum slope angles usually depends upon the interface friction angle of the GCL. This should be measured either in a 300 mm x 300 mm shear box or in a tilt table test of at least 1 m x 1 m in size, with the GCL hydrated in such a way representing site conditions. The way a GCL is hydrated for test purposes greatly influences its performance in that test. The test normal load should cover the normal loads expected on site. Further advice can be obtained from the manufacturers.

2.5.7 Hydration of GCLs

Normally GCLs do not need to be artificially hydrated. Either through rainfall or by the natural transpiration of soils, GCLs receive sufficient moisture to hydrate and act as a barrier to other liquids. However, if the GCL could come into contact with other liquids, e.g. oil, before it hydrates, it might be necessary to artificially hydrate the GCL beforehand. This is best done after the cover layer has been installed. Advice on such applications should be required from the manufacturers.

2.5.8 Overlaps

Overlaps and joints are always the weakest parts of a sealing system. With GCLs, some manufacturers recommend only 150 mm overlaps, others 300 mm. It is the author's opinion that 150 mm does not allow for any safety margin and he would like all GCL overlaps to be about 300 mm. Inaccuracies during installation, movement of the cover material due to the installation, movement due to settlement or local deformations and shrinkage movement could all act together leaving an open overlap.

Different manufacturers recommend different methods to seal their overlaps. Those with thin geotextiles say that no extra bentonite paste or powder is required to seal their overlaps, as the bentonite in the middle hydrates together. This opens the question that if the bentonite hydrates through the geotextile to seal the joints, then it can also hydrate through the geotextile in the rest of the mat and be lost to the soil in contact with the GCL. Thicker geotextiles have the problem that the bentonite paste or powder placed on the overlap does not penetrate the geotextile to the bentonite core, leaving an area for water to pipe through the overlap. This can be counter-acted by installing the bentonite as a thin paste first, pushing it well into the pores of the thick geotextile to achieve contact with the bentonite core and supplementing this with a second layer of thicker bentonite paste. Alternatively, one manufacturer impregnates the thick geotextile with dry bentonite powder during the manufacturing process. This seems to be the best solution.

2.6 *Quality control*

As Mr. P. Ruardi of the Ministry of Housing, Planning and Environment [lit. 9] has already indicated, a quality assurance with regard to sealing is of crucial importance. The major advantage of a GCL is that it can be manufactured under quality assurance. Needle punched GCLs can be applied in almost all weather conditions.

2.6.1 Testing

Most GCL manufacturers carry out quality control tests on their products and these results should be requested by the contractor purchasing the material. Additionally, independent tests should be carried out. It is also possible to specify the tests and frequency the tests that have to be carried out in the tender documents.

Some manufacturers have developed their own internal control tests to confirm the quality of their products. For example 'Naue Fasertechnik GmbH & Co.KG' of Germany carries out frequent peel tests to confirm the fibre connection strength reinforcing the components of their Bentofix GCL.

2.6.2 Quality control

Quality control should be carried out in the following ways:

2.6.2.1 Manufacturers internal testing

The frequency of such tests can also be stated in the specifications.

2.6.2.2 Independent testing

This can be carried out on samples from the factory or from the site. The independent tests must use the same test methods as the manufacturer or else there is no acceptable way to compare results.

2.6.2.3 Basic independent test certificates

These are usually special tests controlling the general function of the GCL and are not suitable for monitoring the production quality. Examples are: k-value of the overlap, methane gas impermeability, damage resistance to drop energy, erosion resistance of the geotextiles etc. These requirements can become part of the specification if applicable.

2.6.2.4 Installation control

Ensure that the people installing the GCLs have a copy of the manufacturers' installation guidelines on site. Make a "Method Statement" part of the specification. In such a statement the way in which a contractor intends to transport, handle, store and install the GCLs and the cover layer is fixed. Site practice such as no walking on overlap areas, what to do if the GCLs hydrate before the cover layer is installed etc. can be fixed in advance in this method statement.

2.6.2.5 Construction quality control and assurance

Sometimes an independent consultant is employed to check the rolls on arrival at site and whether the materials are installed as required in the specifications, manufacturers' recommendation and/or the method statement.

2.6.2.6 Installation plan

It is good practice to write into the specifications that the contractor needs to provide an installation plan indicating the roll-number and the location of the roll. This is a useful control to compare test results with performance on site, should a question on performance be made later during the life of the project.

3. DESIGN

The following application of GCLs may occur:

- If the requirements to the subgrade are low and compaction of sand-bentonite-layers may be

impossible/difficult, than a GCL may be the better solution;
- It is almost impossible to apply a conventional mineral sealing (SAM or CCL) on a geomembrane. Therefore, in composite sealings, it is always preferred to place the geomembrane on top of the mineral sealing.

Geomembrane beneath a mineral sealing has the advantage that the mineral sealing is not chemically attached by the released percolate or landfill gas. Dehydration of the mineral sealing is also avoided (if it could ever take place beneath approximately 1 m of soil). Geusebroek gives a number of examples in his article "Discussie noodzakelijk "(Discussion necessary)
[lit. 8] of a 'geomembrane beneath' construction. "At first he indicates that the geomembrane is most resistant against the percolate. Furthermore is the mineral layer embedded in a clean environment, so that the functioning of the mineral layer can easily be controlled by using an intermediate layer. Additionally, the connection of top and bottom sealing is simple".

3.1. *Steep slopes*

A mineral sealing provided with a needle-punched GCL can even be applied vertically. Because the bentonite powder is evenly spread over the mat, erosion stable, and is secured in very small "rooms" (millions per square metre), the GCL is a good sealing in every possible position

In particular at cappings of old landfill sites it regularly occurs that the slopes are constructed very steeply. In situations like this it is advised to have a look at the slope stability. The following points are of importance when applying a GCL as a mineral sealing [lit. 14]:
- the internal stability of the GCL
- the external stability.

The limited angle of friction of the bentonite seems to be disadvantageous for the internal stability of the mat. However, this disadvantage is counter-acted by the very intensive needle punching of the GCL. It is possible to have the frictional forces taken over by the needle punching. An enormous number of single fibres (over 2-3 million fibres/m^2 in Bentofix) take care of a very good connection between the carrier and the cover geotextile and the bentonite. In this way, an equal, direction-independent shear connection is realised. The normative friction joint depends on the top load, the extent of consolidation of the GCL and the connecting strength (dependent on the intensity of needle punching), This normative friction angle can manifest itself.:
- outside the GCL, which means between the top and base geotextile and the adjacent soil (or other geotextile material)
- inside the GCL (on bentonite layer level).

The slope with Bentofix can be designed in such a way that the critical friction angle is outside of the GCL. In the laboratory of "Naue Fasertechnik" tests were carried out the relation between the connecting strength and slope stability (see figure 1)

In figure 2 is the relation between connecting strength, slope gradient and top load specified. In this figure one can, for example, see that with a top load of 0,50 m and a slope of 1 : 1.5 a connecting strength of > 30 N/10 cm is already providing a safety of 3.

4. PRACTICAL EXPERIENCE

4.1 *U.S.A.*

In the U.S.A., the country where the Wyoming bentonite comes from, they are very experienced in applying GCLs for landfills. Many testmethods for GCLs are standardised in accordance with ASTM-standards. At a lecture for the NGO "Geosynthetic containment systems for landfill liners and covers"[lit.15], R.M. Koerner, managing director of the Geosynthetic Research Institute of the University of Drexel Philadelphia, indicated that a prefab GCL as a capping makes a far better solution than a clay or a

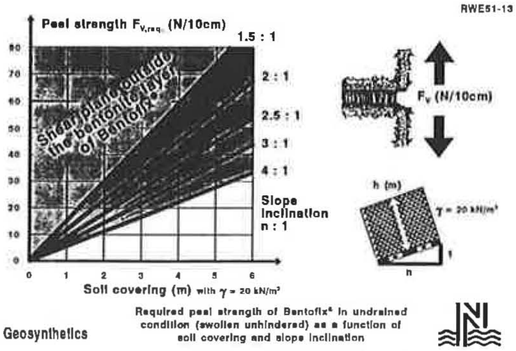

Figure 1: representation of the required connecting strength of Bentofix in undrained condition (expanded freely) as a function of the top load and the slope gradient.

sand bentonite layer. Research and experience show that a GCL can be used as a single sealing system as well as a composite sealing element and is efficient as a GCL or SAM.

4.2. *Europe*

All over Europe and in particular in Germany, a lot of experience is gained by making use of GCLs as part of a capping of landfills. In Germany, millions of square metres of GCL were placed as an alternative to decimetres-thick mineral sealings. Even the first generation of GCLs were regarded as equals to thick clay layers. In Germany they have also formulated many DIN-standards for determining the parameters of a GCL.

4.3 *The Netherlands*

The first hundreds of thousands of GCLs have also been installed in the Netherlands by now. They are applied as base-, between- or capsealing of landfills and in all kinds of civil applications. The latest generation of GCLs are regarded by many authorities in the Netherlands as equal to sand-bentonite layers (SAM) with a thickness of at least 0,50 m.
Advantages of the GCL with regard to conventional sealings are, amongst others:
- quality assurance
- installation time
- independence of weather conditions (with needle punched GCLs)
- no compaction of the layer demands
- less use of primary building materials, such as gravel and sand
- geomembrane be applied beneath the mineral sealing as well.

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