Indicators for Selection of Protection Layers for Geomembranes

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ABSTRACT: With respect to the rapid and permanent drainage above a landfill base seal very coarse-grained materials are used today for the drainage layer. The mechanical protection of the geomembrane against impermissible loads, such as perforations and deformations of the surface resulting from punctate pressure loads, can especially be provided by specifically developed geotextile protection layers. This paper gives a summary of the experience gained in several years of examinations. Furtheron, indications for the selection of the protection system at different loads, which have to be expected in a landfill, are supplied. In Germany at least, new protection systems will probably be preferred when extreme landfill heights are expected. These new protection systems are also described in this paper.

1 INTRODUCTION

Fig. 1 shows the base sealing system for a landfill for residues published in Germany by the TA Siedlungsabfall (1993). In order to protect the geomembrane, which had been manufactured and installed with a lot of work and costs, against overloads or even perforations a protection layer is absolutely inevitable between drainage layer (grain size 16/32 mm) and geomembrane. The efficiency of a protection layer can be assessed by applying the following criteria:

- no damage (notches) in the surface of the geomembrane,
- no impermissible changes in the thickness of the geomembrane as a result of higher loads at individual spots, and
- no impermissible deformations of the geomembrane resulting from local curves and bendings.

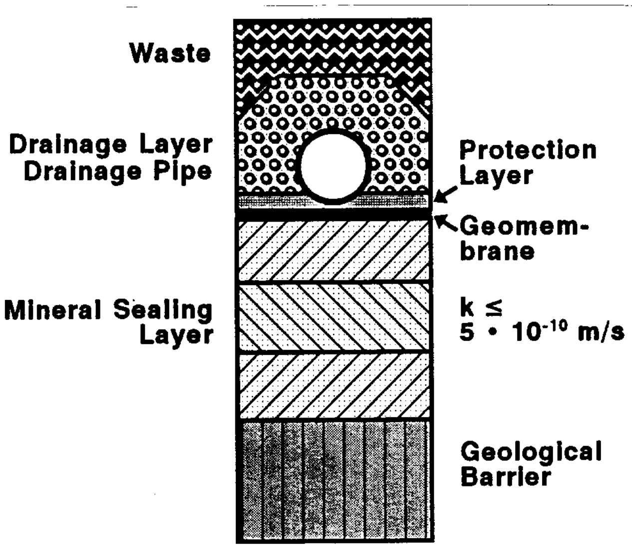

Figure 1 Composition of the base sealing system according to TA Siedlungsabfall (1993) for landfill class II

2 LONG-TERM PERFORMANCE LOAD BEARING TEST

Since in Germany the obligatory certification for protection layers did not yet exist when this paper was printed, the fulfilling of the phrased requirements has to be proven -as it was up to now- by independent testing institutes. At present, the guideline for the certification of geomembranes, which is published by the Bundesanstalt für Materialforschung und -prüfung in Berlin -BAM- (Federal Institute For Material Testing And Research) and which proposes criteria for the realization and assessment of a long-term performance load bearing test, offers some assistance. It is the purpose of the long-term performance load bearing test to simulate the situation at a landfill base as realistic as possible and to examine the constitution of a geomembrane after it had been loaded.

Fig. 2 schematically shows the set-up of a long-term performance load bearing test. In general the layers are arranged as follows (from top to bottom): pressure plate (minimum diameter 30 cm), levelling sand layer, the envisaged drainage material (usually 20 cm gravel 16/32 mm), the protection layer to be tested, the selected geomembrane (usually made from HDPE in a minimum thickness of 2.5 mm), soft metal sheet (organ pipe sheet) and elastomer support layer (usually in a thickness of

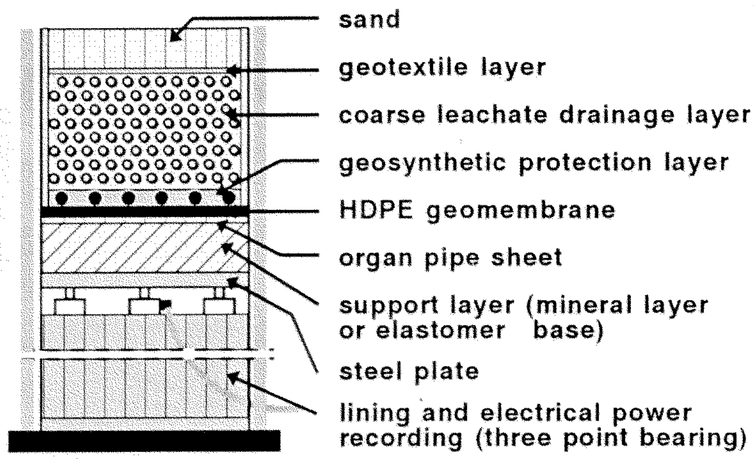

Figure 2 Example of a long-term performance load bearing test

2.0 cm and a Shore hardness of 50 °A).

The test pressure P_P is calculated with the load P_A which is calculated from the designed maximum height h_A of the landfill and the average density γ of the waste body (usually 15 kN/m^3 are assumed).

$$P_P = 1.5 \bullet P_A = 1.5 \bullet h_A \bullet \gamma = 22.5 \bullet h_A \qquad (1)$$

Further marginal conditions for the test are: temperature 40 °C, load $P_A \leq 600$ kPa and test duration 1000 hours. In case of loads $P_A > 600$ kPa the test set-up (for instance the selection of the support layer) and a possible quick-motion effect achieved by excessive loads or temperatures have to be discussed. Apart from the test evaluation after 1000 hours the time dependent changes of the local deformations in the geomembrane after 10 and 100 hours should be considered for an evaluation. Here a convex course of curve in the deformation-time-diagram has to arise so that for longer periods as well only limited deformations have to be expected. The evaluation criterion for the protection layer is:

$$\varepsilon_{max} \leq 0.25\ \% \qquad (2)$$

with ε_{max} as deformation (calculated as elongation when a spherical segment is assumed) in the geomembrane in %.

The protection layer is considered as suitable when, immediately after the 1000-hour-test, the dents determined in the smooth geomembrane do not exceed maximum deformations of $\varepsilon_{max} = 0.25$ %. The deformations appearing in the geomembrane during the test can be determined by measuring the metal sheet arranged between support layer and geomembrane. The deformations impressed in the metal sheet are sensed computer-controlled in a scanning-pattern or along at least 6 diagonal lines. Sehrbrock and Rodatz (1993) compare comprehensive tests with various deformation measurement methods for different protection layers. It is evident that the scanning-pattern has to be preferred.

Fig. 3 and 4 show examples of scanning-patterns (distance of the measuring points 5 mm) with 10-fold vertical magnification.

Sehrbrock and Rodatz (1993) examined in their test series the following products which they presently envisage for the use as protection layers:

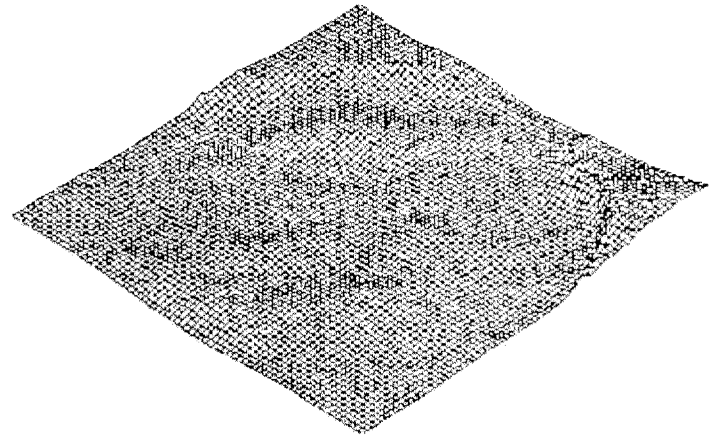

Figure 3 Scanning-pattern of a metal sheet, protection layer A (Sehrbrock and Rodatz, 1993)

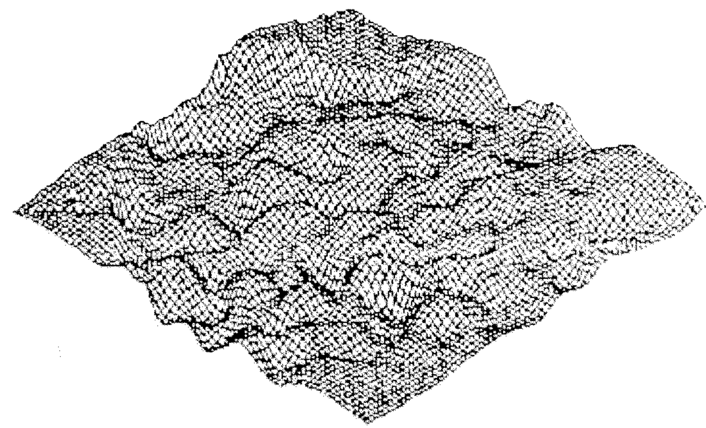

Figure 4 Scanning-pattern of a metal sheet, protection layer C (Sehrbrock and Rodatz, 1993)

- protection layer A:
  1200 g/m^2 mechanically bonded HDPE nonwoven fabric and sand 0/2 mm (installation thickness d_S = 10 cm),
- protection layer B:
  1200 g/m^2 mechanically bonded HDPE nonwoven fabric and gravel 2/8 mm (installation thickness d_G = 15 cm),
- protection layer C:
  2000 g/m^2 mechanically bonded HDPE composite material (nonwoven and woven fabric) and
- protection layer D:
  3000 g/m^2 mechanically bonded HDPE composite material (nonwoven and woven fabric).

The test pressure was chosen to be P_P = 1 MPa. The duration of loading was 100 hours (for the tests with the mineral support layer) resp. 48 hours (for the tests with the elastomer support layer). The drainage material gravel with the grain size 16/32 mm was installed as loose filling.

For the evaluation of the condition of the whole sample the arithmetical average from the number of the deformations determined for each individual measuring point $\varepsilon_{max,am}$ (Table 1) is more suitable than an evaluation only by means of the maximum value ε_{max}.

As it could be expected, the two combinations nonwoven fabric/mineral layer (protection layer A and B) received the best results. Composite materials (protection layers C and D) have values which are up to 29 times higher than those of the two combinations nonwoven fabric/mineral layer.

Table 1 Deformations in % according to Sehrbrock and Rodatz (1993)

Protection layer	Elastomer		Silt	
	$\varepsilon_{max,am}$	ε_{max}	$\varepsilon_{max,am}$	ε_{max}
A	0.027	0.273	0.151	0.829
B	0.044	0.364	0.103	0.667
C	0.779	4.799	0.928	6.332
D	0.743	3.795	0.674	3.583

Both the geomembrane and the metal sheet are of great importance for the transmission of the non-uniform load into the support layer. Thus they influence the result of the long-term performance load bearing test, as was shown by comparative tests without metal sheet resp. without geomembrane.

With respect to the requirements, which today have to be fulfilled by the landfill subgrade and by the mechanical properties of the mineral sealing, only very low or nearly neglectable deformations of the geomembrane result from settlements and settlement differences at the landfill base. It has to be reflected whether the protection effect required in the guidelines with a permissible deformation of the geomembrane of $\varepsilon_{max} = 0.25$ % is fixed by considering the material properties and whether an increase to $\varepsilon_{max} = 0.5$ to 1.0 % might be permissible.

3 LONG-TERM PERFORMANCE PUNCTATE LOAD TESTS

The geotextile protection layer has to be dimensioned so that under the assumed load conditions impermissible loadings in the form of punctate dents or perforations of the geomembrane can be absolutely excluded. The central measuring factor resulting from this requirement is the depth and the shape of the surface deformation resp. the perforation of the geomembrane under selected punctate loads.

Therefore testing devices were produced (Fig. 5) with which the performance of geotextile protection layers can be examined under practice-oriented and reproduceable conditions (Knipschild, Saathoff and Bassen, 1988, and Saathoff, 1991). Essential components of the long-term performance punctate load test are the pressure device with exchangeable indentor (cone 45° and 60°, truncated cone 45° and 60° and sphere ∅ 10, 15 and 20 mm), measuring of the deformations and spreader bar resp. load plate for the application of the load. The testing device is constructed so that support layers consisting of, for example, steel, hard foam, elastomer or soil can be installed.

It was found that testing results gained with the steel support layer are not applicable to other support layers and that, compared to clay support layers, the results received with elastomer support layers do not provide sufficient safety. Furtheron, it was evident that the temperature (up to 60 °C) has a considerable influence on the result

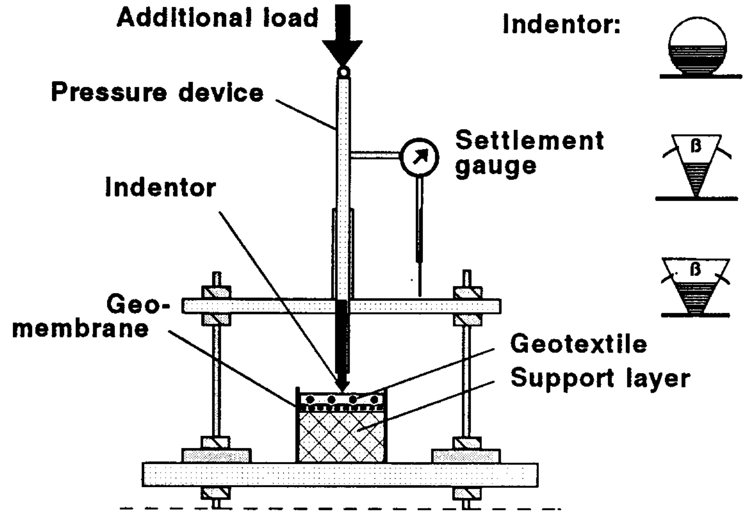

Figure 5 Set-up of the long-term performance punctate load test and applied indentors (Saathoff, 1991)

(Saathoff, 1991, and Brummermann, Kohlhase and Saathoff, 1993).

In order to record the settlement behaviour of a sand support layer the long-term deformation lines determined without protection layers are subtracted from those with a protection layer (dependent on indentor and load). The results are difference long-term load deformation lines $\delta d_t = f(t)$.

Fig. 6 shows the comparison between different indentor/load combinations for the sand support layer and the combination "2.5 mm HDPE geomembrane with a 2400 g/m^2 mechanically bonded HDPE staple fibre non-woven fabric".

If such a line runs parallel to the abscissa, a good protection effect may be assumed. The inclination and the absolute difference remaining thickness are further criteria. The thickness of the geomembrane determined after the test is finally decisive for the evaluation of the protection effect of a geotextile (Saathoff, 1991).

It is the aim of most recent tests to establish a connection between idealized tests with pressure plates and more realistic long-term performance load bearing tests with the original drainage material (Brummermann, Kohlhase and Saathoff, 1993).

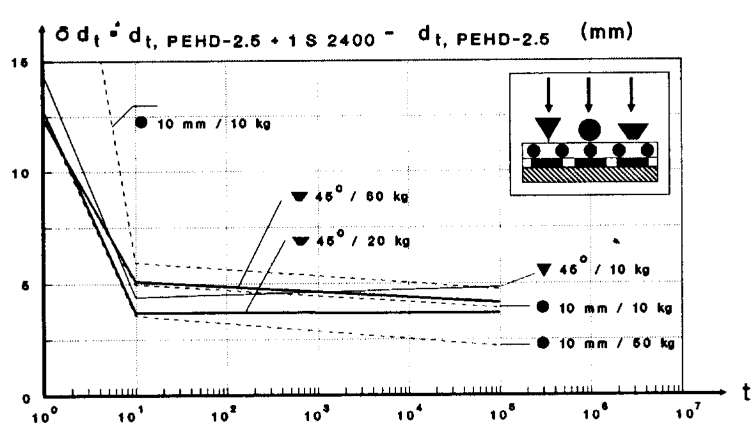

Figure 6 Selected long-term load deformation lines, support layer: sand, geomembrane: 2.5 mm HDPE, protection layer: 2400 g/m^2 mechanically bonded HDPE nonwoven fabric (Saathoff, 1991)

4 INDICATIONS FOR THE SELECTION OF PROTECTION LAYERS

Table 2 gives rough indications for the selection of protection layers provided that the German guidelines (for instance validity of the deformation criterion $\varepsilon_{max} = 0.25$ %) and the drainage material gravel 16/32 mm are used.

Table 2: Rough indications for the selection of protection layers for drainage layers consisting of gravel 16/32 mm (Saathoff and Johannßen, 1994)

Waste height (m)	Geosynthetic	m_A (g/m^2)
$0 \leq h \leq 2$	nonwoven fabric	600
$2 \leq h \leq 10$	nonwoven fabric	1800
$10 \leq h \leq 25$	composite material consisting of nonwoven/woven fabric	3000
$25 \leq h \leq 40$	GCL	4200
$h > 25$	composite material to be filled on site with mineral material	> 50,000

The experts agree that a substantial improvement of the protection layer is achieved when mineral components are part of the protection system.

Already in 1989, tests on the protection effect of geosynthetic clay liners (GCLs) provided positive results. Recent developments specify geotextile composite materials which are filled on site with mineral materials for the protection layer. The *Depomat®* protection system (Fig. 7) is one example for the new generation of protection layers. For *Depomat® C 25*, for instance, a 400 g/m^2 mechanically bonded HDPE support geotextil is connected in the factory to a 25 mm HDPE convoluting fibre layer. After the convoluting fibre layer has been rolled out on site, it is filled with quartz sand by using the dry blowing method. The defined thickness of the convoluting fibre layer and the uniform and erosion resistant sand filling guarantee a reliable protection of the geomembrane against damage and deformation.

After the convoluting fibre layer has been filled with the quartz sand, a 400 g/m^2 mechanically bonded HDPE composite material is installed as a filter layer against the drainage layer.

Table 3 shows comparative deformation values. When the *Depomat®* protection system is used the strict German guiding values can be followed even in cases where the expected landfill height exceeds 100 m.

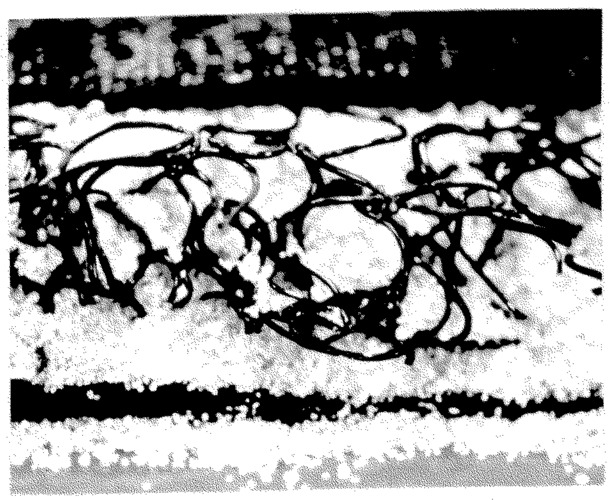

Figure 7 Composition of the *Depomat®* protection system

Table 3: Determined deformation values of different protection layers for a geomembrane, when gravel 16/32 mm and landfill heights of approx. 40 m are given

Geosynthetic	m_A (g/m^2)	ε_{max} (%)
Nonwoven fabric	1200	> 3.5
Nonwoven fabric	1800	> 1.5
Nonwoven fabric	3000	> 0.5
GCL Bentofix® C	4200	≈ 0.2
Depomat® C 25	> 50,000	<< 0.1

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