Protection Layers for Geomembranes: Effectiveness and Testing Procedures-

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ABSTRACT: Geomembranes in composite liners of landfills may not be damaged by coarse grains of the drainage layer. In Germany different types of protection layers are used: mineral layers, geosynthetic layers or combinations of both. Suitable protection layers, especially clayfilled and sandfilled mats, are in development. A standardized procedure for testing the mechanical effectiveness of protection layers is required. Selected results of research programmes to investigate the effect of different parameters on the protection effectiveness and to develop a standardized testing procedure and evaluation method are described. Preliminary conclusions are drawn.

1 INTRODUCTION

Geomembranes (in Germany usually HDPE and 2.5 mm thick) in sealing systems of landfills (Fig. 1) may not be damaged by coarse particles of the drainage layer (in Germany usually gravel 16/32 mm). Notches and scratches have to be prevented and the strains are limited. A protection layer between geomembrane and drainage layer is necessary. New types of protection layers, e.g. clayfilled or sandfilled geotextiles, and suitable procedures for testing the effectiveness of protection layers are in development.

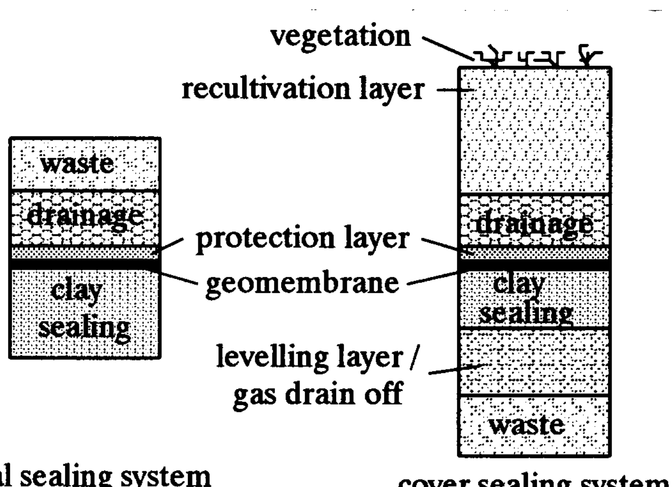


Fig. 1 Structure of combined sealing liners in German landfills according to the Technical Regulations

2 TYPES OF PROTECTION LAYERS

Table 1 gives an overview about different types of protection layers and some comments on their advantages and disadvantages. Combined protection layers seem to be suitable. They combine the advantages of mineral and of geosynthetic layers.

3 TESTING THE EFFECTIVENESS OF PROTECTION LAYERS

The mechanical effectiveness of proctection layers has to be investigated. Many other aspects have to be considered, e.g. chemical and biological resistance, practicability of installation, friction between protection layers and geomembranes. This paper is focussed on the mechanical effectiveness of protection layers.

In general the testing system of pressure tests has the same structure as sealing liners in landfills (Fig. 1 and Fig. 2). A non-elastic metallic sheet of a tin-lead alloyage is an aid to conserve the maximum deformation of the geomembrane under load and to determine the strains. In general the strains caused by coarse grains of the drainage layer are the most critical evaluation criteria. A standardized determination procedure of the strains is necessary. Table 2 shows different types of testing the protection effectiveness. Strain data resulting of pressure tests with original drainage material are scattering within a wide range because the arrangement of the natural drainage material is randomly and varies from test to test. Tests with geometrically defined penetrators are better to find quantitative strain results, but there is no direct relation between such tests and individual liner systems in landfills. This relation has to be established by pressure tests with gravel. Thus both types of tests are necessary.

Table 1 Types of protection layers.

Group	Type	Comments
mineral layers	sand or other materials	- mechanical effective - resistant to chemical and biological stresses and high temperatures - difficult installation in slope areas
geosynthetics or similar layers	HDPE or PP needle-punched non-wovens with different masses per area	- easy installation in slope areas - small thickness - possibly not sufficiently resistant to chemicals and high temperatures
	non-wovens and wovens	
	non-wovens and geogrids	
	rubber mats	- still no experience
combined geosynthetics and mineral layers	geotextiles beneath minerals	- difficult installation in slope areas
	sandfilled mats	- small thickness - mechanical effective - possibly problems in the contact area of single mats and in the contact area to the drainage layer (filter stability)
	clayfilled mats	- small thickness - longtime function of geosynthetics due to low shear resistance of the clay

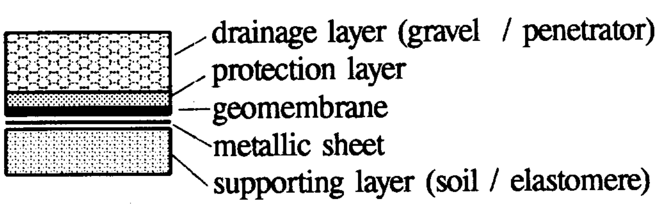
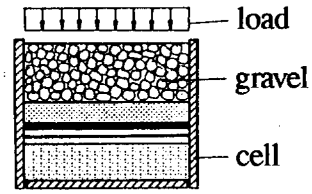
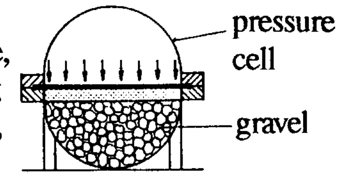
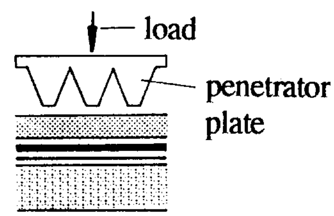
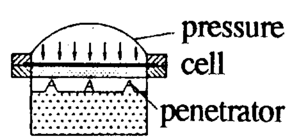


Fig. 2 Structure of testing systems for pressure tests

Table 2 General types of testing mechanical protection effectiveness.

Type of test	Type of loading	Schematic figure
1 pressure tests with original drainage material	a load against drainage material (Sehrbrock, 1993)	
	b load against geomembrane, no supporting layer (Steffen, 1990)	
2 pressure tests with geometrically defined single penetrators or groups of penetrators	a load against protection layer (Brummermann et al., 1993)	
	b load against geomembrane, no supporting layer (South West Research Institute, 1988)	

4 SELECTED TEST RESULTS

4.1 Pressure test results with gravel and penetrator plates

To compare the results of tests with gravel in cells with a diameter of 35 cm and with geometrically defined penetrator plates tests with the same parameters but varied loads were performed (Table 3). Fig. 3 shows the penetrator plate developed to simulate gravel 16/32 mm.

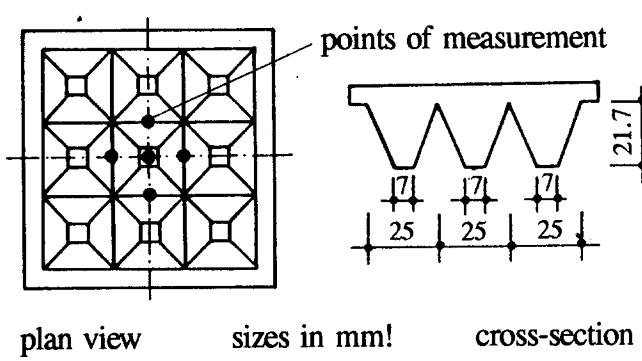
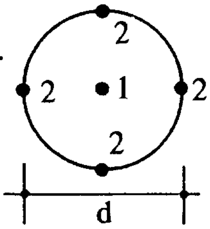


Fig. 3 Penetrator plate to simulate gravel 16/32 mm

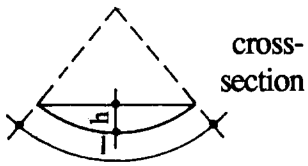
Fig. 4 explains the methods of determining the strains and Fig. 5 shows the strains vs. load. The results of the tests with gravel scatter more. But the maximum strain values of tests with penetrator plates and with gravel are in the same order and show a similar linear increase of the strains with load. Tests with penetrator plates seem to be on the safe side compared to tests with gravel.

a) "Circle segment method" for tests with penetrator plates

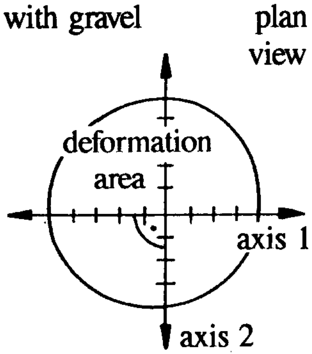


- measurement of the heights of the deepest point 1 and the highest points 2
- calculation of the strain:

$$\text{strain} = \frac{l-d}{d} * 100 \ [\%]$$



b) "Polygon method" for tests with gravel



- selection of significant deformations
- two measure axes with the centre in the deepest point
- measurement of height h in constant distances of 3 mm
- calculation of partial strains:

$$\text{partial strain} = \frac{\sqrt{(h_{i+1}-h_i)^2 + 3^2} - 3}{3} * 100 \ [\%]$$

- calculation of average strain from maximum to maximum of both axes

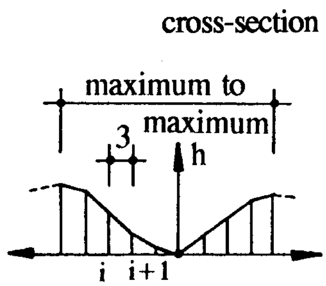


Fig. 4 Methods of strain determination

Table 3 Parameters of the test series

type of test	1a, 2a (Table 2)
time	100 h
temperature	40° C
load	300 to 1200 kPa beneath the system
drainage layer	gravel 16/32 mm, penetrator plate with truncated pyramids (Fig. 3)
protection layer	mechanically bonded non-woven filament PP-geotextile (mass per area about 2000 g/m²)
geomembrane	HDPE, smooth, 2.5 mm thick
supporting layer	elastomere shore 50 A (15 mm thick)

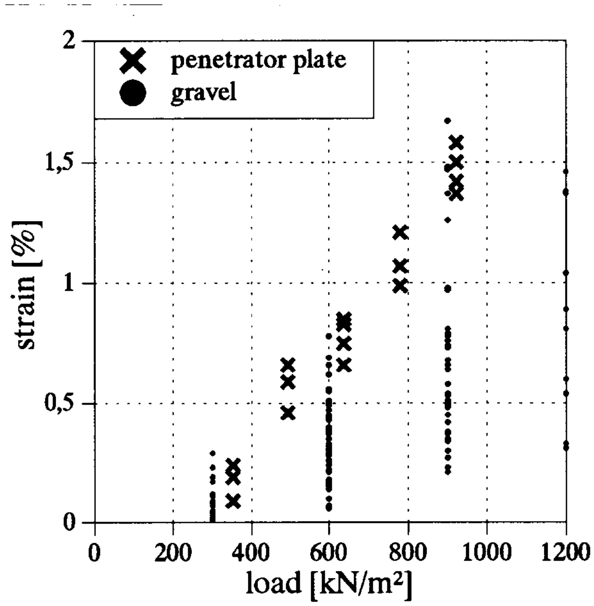


Fig. 5 Strain vs. load

4.2 Pressure test results with conservation of testing system under loading conditions

Different protection layers were tested under cyclic loading of 1 MN/m² in a compression cell with a diameter of about 30 cm to investigate the penetration of coarse grains of gravel into the protection layer. To fix the status of penetration and the deformation of the geomembrane the system was partly grouted with epoxid resin under load. The main advantage of this procedure is that after hardening of the resin the complete cylindrical body consisting of the drainage and the protection layer can be removed from the test cell and cut into slices. The contact area between drainage and protection layer under loading conditions is fixed also. The grouted body and the slices may be used for deformation investigations etc.

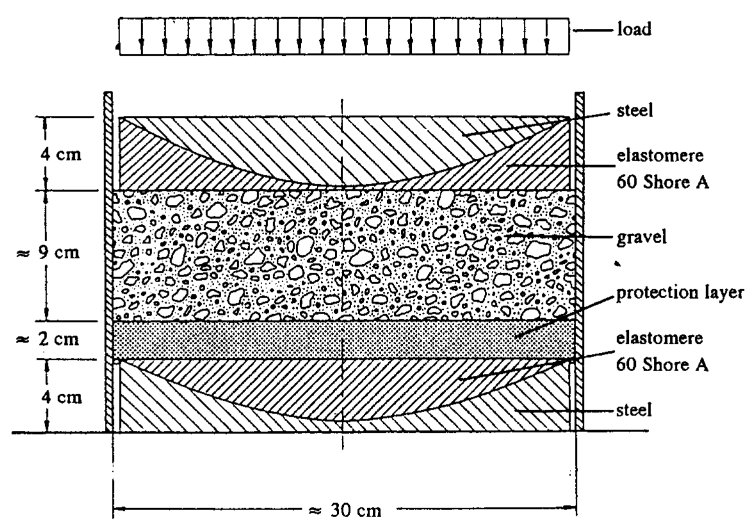


Fig. 6 Testing system

A 10 cm thick layer of gravel 16/32 mm and a 2 to 3 cm thick protection layer of sand 0/2 mm were tested with 1, 10 and 100 loading cycles. The scheme of the testing system is shown in Fig. 6. Special pressure plates made out of a shore 60 A elastomere and steel were used to simulate possible deflections of liners in situ. Significant penetration of gravel into the sand layer related to the number of load cycles did not occur.

In order to compare the effectiveness of geotextile and sand protection layers both were tested with 10 loading cycles. A sand layer and a 3000 g/m² needle-punched non-woven HDPE-geotextile were investigated. Fig. 7 shows schematic cross-sections of testing systems after grouting under load.

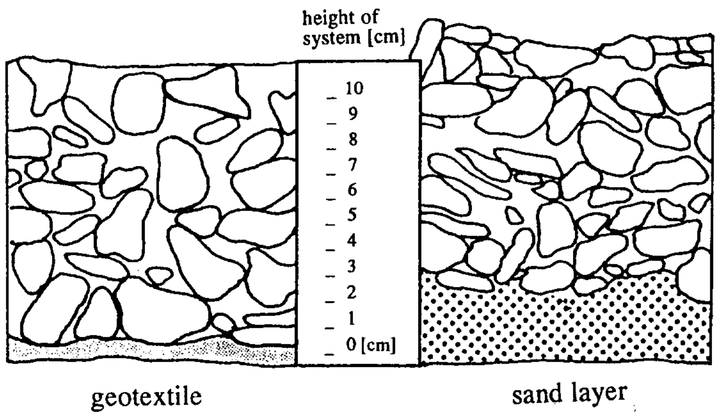


Fig. 7 Cross-section of grouted testing systems with different types of protection layers

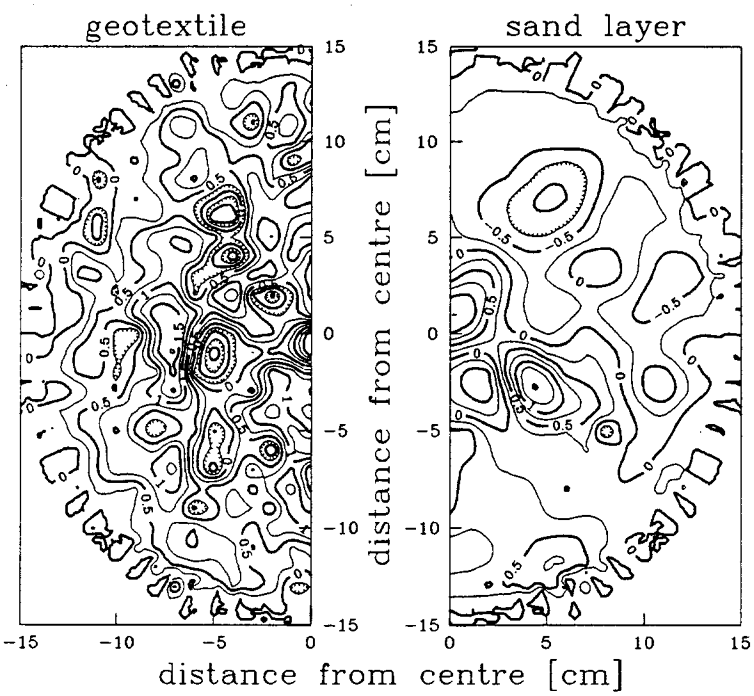


Fig. 8 Lines of equal vertical displacements underneath a geotextile and a sand protection layer

The geotextile with the initial thickness of about 20 mm was compressed to a thickness of about 5 mm. Fig. 8 shows plots of the deformed geomembrane surfaces with contour-lines for every 0.25 mm vertical displacement. Concentrations of contour-lines indicate highly deformed areas. The maximum vertical displacement and the concentration of deformations underneath the geotextile are much higher than underneath the sand layer. But grains of the gravel did not perforate the geotextile.

5 CONCLUSIONS

Pressure tests with penetrator plates are suitable as standardized tests to investigate the mechanical effectiveness of protection layers. Tests with gravel are necessary to calibrate tests with penetrator plates but are less suitable as standardized tests, because the results scatter within a wide range and therefore a higher number of equal tests is necessary to get representative data for comparison purposes.

Mineral and geosynthetic protection layers in liner systems of landfills have advantages and disadvantages concerning the mechanical effectiveness, the installation, the thickness etc. (Table 1 and chapter 4.2). Prefabricated mat-shaped geotextile containers with thin sand inlays can combine the advantages of geosynthetics and minerals.

6 ACKNOWLEDGEMENTS

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