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GEOTEXTILE/"GEOSPACER" COMPOSITES FOR ENVIRONMENTAL PROJECTS

COMPOSITES GEOTEXTILE/«GEOSPACER» POUR DES PROJETS D'ENVIRONNEMENT

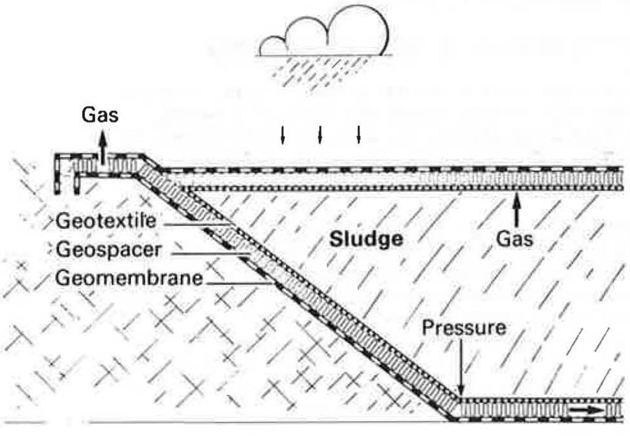
GEOTEXTIL/„GEOSPACER"-VERBUNDSTOFFE FÜR UMWELTSCHUTZPROJEKTE

As an overall label for the synthetic materials used in civil engineering, this paper employs the term Geosynthetics. To complement the categories of geotextiles and geomembranes, the category of "Geospacers" is introduced and defined here to denote all geosynthetics designed to permit in-plane transportation of gases or liquids.
Uses of these materials in the controlled storage of wastes are discussed in detail.
With reference to measurements by the Enka Research Institute (Arnhem) and field experience with PA geospacers, the utility of various types of geospacers in combination with geotextiles and geomembranes is assessed.

Für die verschiedenen im Erd- und Grundbau eingesetzten synthetischen Produkte wird in diesem Referat die Sammelbezeichnung "Geosynthetics" verwendet. Neben "Geotextilien" und "Geomembranen" wird die Gruppe der "Geospacers" eingeführt und definiert. Es handelt sich dabei um diejenigen Geosynthetics, die dazu entworfen worden sind, den Transport von Gasen oder Flüssigkeiten in der Ebene zu übernehmen. Die Anwendungsmöglichkeiten für diese Produkte in bezug auf sichere Lagerung von Abfallstoffen werden eingehend besprochen. Anhand von Messungen im Enka-Forschungsinstitut in Arnheim und der mit PA-Geospacers gemachten Erfahrungen in der Praxis wird auf die Brauchbarkeit verschiedener Geospacer-Typen in Verbindung mit Geotextilien und Geomembranen näher eingegangen.

INTRODUCTION

As living standards increase, so does consumption of raw materials and foods. In several countries this has created a critical situation with respect to the storage and decomposition of environmentally hazardous wastes. Thus waste-water treating facilities often produce large volumes of sludge of a quality which is unsuitable for use as fertilizer on arable land.



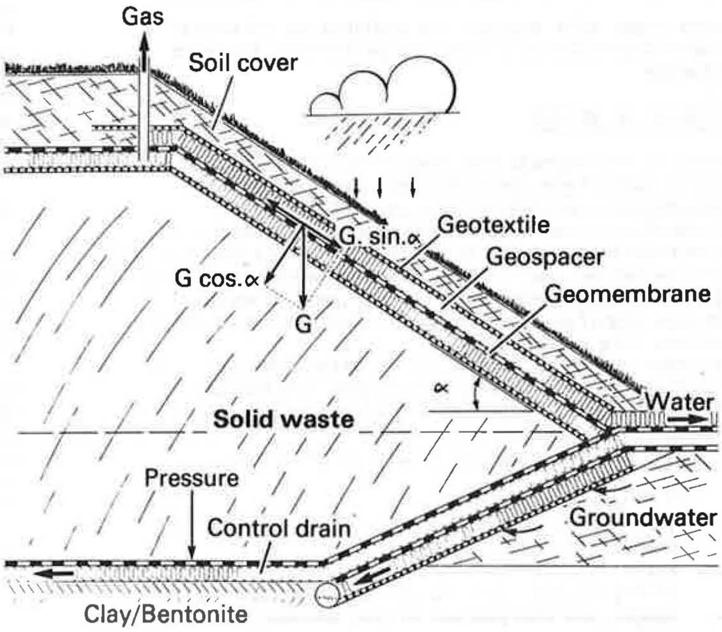


Figure 1. Geosynthetics in waste disposal projects.

In the past decades chemical wastes have in many places come to be admixed with domestic wastes. Depending on the nature of the subsoil, the aggressiveness of the leachate and the use of the groundwater available locally, measures may be needed to isolate the leachate, or to prevent the formation of leachate by sealing the tip from above.
The organic matter in a tip reacts with water to form gases (such as carbon dioxide and methane) if no oxygen is admitted. The uncontrolled escape of such gases has on several past occasions led to serious accidents.
Techniques to refine the gas mixtures produced for subsequent use as a source of energy are increasingly becoming available.
Towards the solution of the environmental problems outlined above, geotextiles, geomembranes and "geospacers" - whether used individually or as a part of prefab composites - may make valuable contributions.
The term "Geospacer" is hereby introduced and is defined as follows:

A GEOSPACER is a three-dimensional, geometrically defined, bulky structure composed of thermally or mechanically bonded synthetic filaments or of profiled rigid plastic sheeting.

All synthetic materials currently used in civil engineering might be classed under the label Geosynthetics (1), as follows:

	Geotextiles	(two-dimensional fabrics and non-wovens for reinforcement and separation)
Geosynthetics	Geomembranes	(liners as liquid or gas barrier)
	Geospacers	(three-dimensional grids, mats and other structures for transport of liquid or gas)

This paper will discuss the application potential of these materials or a combination thereof in waste storage.

STORAGE OF WASTES

Both in the storage and dewatering of sludge and in solid-waste tips, geomembranes, geotextiles and geospacers - whether singly or in the form of composites - can make an important contribution to constructions serving to protect the environment from contamination. Particularly the replacement of heavy layers of clay and gravel by thin geosynthetics brings significant increases in the available tipping volume (see Figure 2.)
To make the right choice, it is vital that all factors of relevance to the proper functioning of the geosynthetic material are taken into account. These factors include:

a. The maximum volume of liquid or gas to be handled,
as a function of:
- local climatological conditions (precipitation, evaporation)
- water absorption capacity and water permeability of the sludge layer or of the earth cover
- length and inclination of the surface to be drained

b. The long-term residual transmissivity of the geospacer,
as a function of:
- maximum soil or sludge pressure
- the rigidity of the geotextile
- material and structure of the geospacer
- degree of fouling of the drain
- chemical resistance to the leachate or tip gas

c. The stability of the construction,
as a function of:
- the depth of the earth cover
- the length and inclination of the slopes
- the coefficients of friction between the discrete layers in wet condition

d. The filtering capacity of the geotextile,
as a function of:
- the low flow rates in the soil or sludge
- the cohesiveness of the soil or sludge particles
- the discontinuity in structure of the adjoining soil or sludge body
- the structural stability and degree of openness of the filter.

SPECIFIC PROBLEMS OF SLUDGE STORAGE

The sewage sludge first needs to be dewatered until a sufficiently firm mass is obtained with a solids content of at least 35%. In Western Europe, this mass is increasingly being stored in special reservoirs, of the type shown in Figure 1 (left side).
On a smooth geomembrane liner, a stable mineral drain layer can only be provided on fairly flat slopes. However,to increase storage capacity on a given area it is desirable that the slopes should be as steep as possible and that the bottom should be close to the groundwater. Provided that the right geospacer/geotextile composite is chosen, a reservoir with slopes of 1 : 1.5 can be constructed without loss of stability.
For horizontal drainage at the bottom of the reservoir, geospacer/geotextile composites are also suitable. Pressure and particle size distribution of the sludge placed on top are important factors in the selection of the most appropriate material.
Whenever a reservoir which has been filled to capacity with sludge is sealed off, gas is likely to collect under the seal. Practice has shown that for the horizontal transportation of such gas a nylon geospacer based on a thermally-bonded non-woven and capped with a geomembrane is an excellent solution (see also Figure 1, left side)

SPECIFIC PROBLEMS OF SOLID WASTES STORAGE

By contrast with a sludge disposal site, a solid wastes tip usually takes the form of a mound, although excavations may also be encountered. In solid waste tipping the following problems are to the fore:

Permeation through the bottom liner
As a result of recent investigations by the BAM Institute of Berlin on the permeation of organic components through geomembranes (2) a double bottom liner is increasingly being specified for new tips. Incorporation of a control drain between the two liners is still the subject of debate. If geospacers are used here, due allowance should be made for top loads of the order of 200-500 kPa.

Leachate retention
As the tip grows, earth cover is provided every 2 or 3 metres to control odour nuisance. When the tip is completed these earth layers often impede the vertical drainage of precipitation. As a result, leachate may build up in the tip several metres high.

Uncontrolled gas escape
The inhomogeneity in the structure of the tip also complicates prediction of the flow pattern of the gas formed in the tip. Yet it is necessary in the interest of both safety and odour control to regulate the discharge of such gases.

Top seal
Although the matter of the necessity of admitting limited amounts of water to full tips to aid in anaerobic decomposition of the refuse is still being debated (3), older tips without a bottom liner are increasingly being provided with a waterproof cover. Steep slopes are easier to realize with geosynthetics than with conventional materials.
Between the planted earth cover and the refuse, the provision of various geosynthetics should be considered (see Figure 1, right side):

* The sealing can be accomplished with a geomembrane.
  * For the discharge of the tip gas a geospacer may be provided.
  * To carry off excess rainwater incorporation under the earth cover of a geospacer/geotextile composite presents considerable advantages.

All this will bring a significant gain in useful volume (see Figure 2).
The stability of such a construction is a function of the length of the slope, its angle α, the weight of the earth cover and the coefficient of friction φ_{min} between the two smoothest layers (see Figure 1). The capacity to handle excess rainwater and tip gas depends on such factors as the compressibility of the geospacer and its resistance to the gases to which it is exposed.

If friction alone cannot ensure stability of the construction ($G \sin\alpha \geqslant \varphi_{min}\, G \cos\alpha$), the composite in question needs to be anchored down at the top of the slope. In that case the tensile strength of the material must be able to supply the deficiency. Dependent on creep of the material, a safety factor should be allowed for to ensure that the construction has permanent stability.

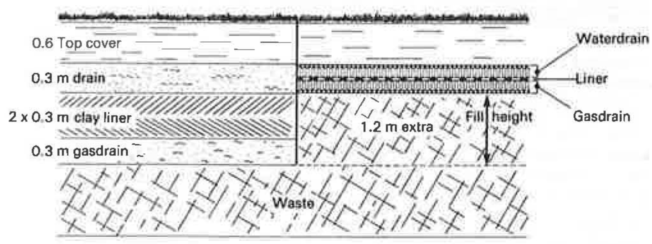


Figure 2. Volume gain by using geosynthetics.

LIQUID VOLUME TO BE DISCHARGED

The maximum volume of leachate to be handled Q_d ($m^3/s.m^2$) is project-specific (see Section 2) and depends in large measure on the coefficient of water permeability (k_f) of the earth (sludge) cover and of the rainfall Q_r ($m^3/s.m^2$).
German Railways (4), for purposes of rail ballast bed design, assume a maximum rainfall of 115 l/s. ha. This translates into a rainfall $Q_r = 1{\cdot}1 .10^{-5}$ $m^3/s.m^2$, of which the part Q_d is to be discharged.

For Dutch conditions Hoeks (6) proposes a maximum value of only 7mm per day at a point 0.3m under the surface of a grassed slope or $Q_d \leqslant 0{\cdot}01.\ 10^{-5}$ $m^3/s.m^2$. Figure 3 shows the volume of water Θ to be handled by the drain per meter width for increasing lengths L of the area to be drained at a rainfall Q_r of $1.\ 10^{-5}$ $m^3/s.m^2$.

The above variables relate as follows:

$$Q_d = Q_r . f . \cos\alpha$$

where Q_d = volume of water to be handled ($m^3/s.m^2$)

Q_r = rainfall ($m^3/s.m^2$)

f = the portion of rainfall not absorbed by the earth cover

α = angle of slope

For a length of slope L the requisite transmissivity $\Theta = L.Q_d$.
The graph shows that, particularly for earth covers which absorb little water($f \approx 1$), the value for the permanent transmissivity Θ of the drain soon needs to be in excess of 1.10^{-4} $m^3/s.m^1$.

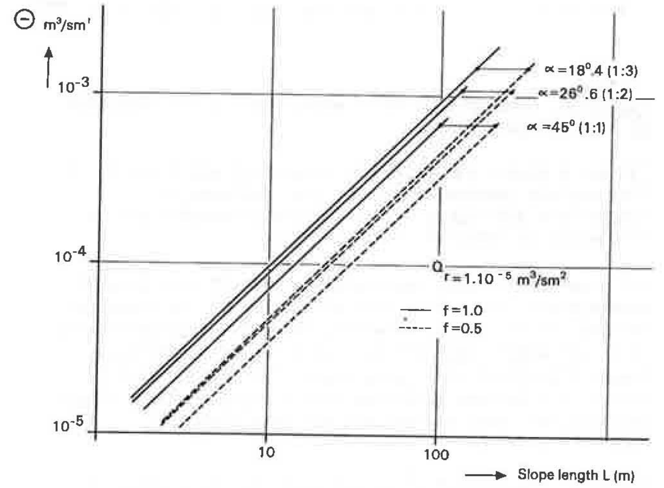


Figure 3. Required transmissivity with increasing slope length and $Q_r = 1.10^{-5}$ $m^3/s.m^2$.

TRANSMISSIVITY OF A GEOSPACER

Enka's Arnhem Research Institute investigated the relation between compressibility and transmissivity of various geospacers. The Institute also assessed the influence of a superimposed geotextile filter on the transmissivity of the geospacer in the event that the compressive strain is exerted by a flexible body of earth or sludge.

Compressibility

The compressibility of the geospacer in wet condition is computed from thickness readings in relation to pressure and time (see Figure 4).
It was found that for PA geospacers of the Enkadrain type, thickness is practically constant after 7 days. Based on this finding, thickness after 7 days under a given load is reported as the thickness at that load:

$$d = f(P,t) \text{ becomes } d = f(P) \text{ for } t = 7 \text{ days.}$$

Transmissivity under flat-plate loading

The transmissivity $\ominus(m^2.s^{-1})$ of the specimen can now be measured by means of the tester shown in Figure 5 for a predetermined plate distance and selected values of the hydraulic gradient $I = \Delta H/L$. Given $\ominus = f(d)$ and $d = f(P)$, the relation between $\ominus$ and P for the drain specimen can now be determined.

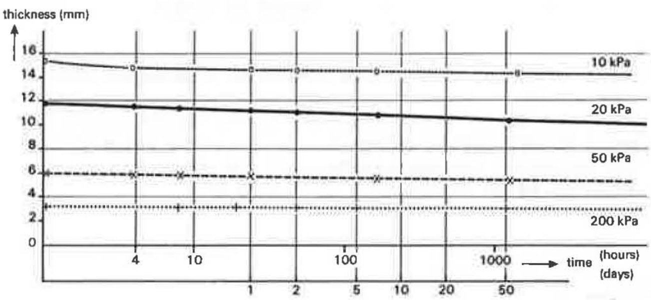


Figure 4. Compression of a water-saturated Enkadrain at various pressures.

Figure 6 plots the relation between $\ominus$ and P at I = 1 for various geospacer types. For purposes of comparison the curve for a polyester needle punched non-woven of $350 g/m^2$ is also given.

Unfortunately these measurements permit no clearcut conclusions because of the disparity of the materials tested. It is clear, however, that the transmissivity of a non-woven geotextile (curve 6) is significant lower than that of a geospacer. This difference is bound to increase with the progressive fouling of the geotextile. This assumption was confirmed by laboratory tests.

Overall, the results suggest that the thickness of the filaments is a major factor (compare curves 1 and 2 with curve 3). A further notable feature is the comparatively low transmissivity of the thin geospacers with the geometrically best defined structures under low loads (curves 4, 5).

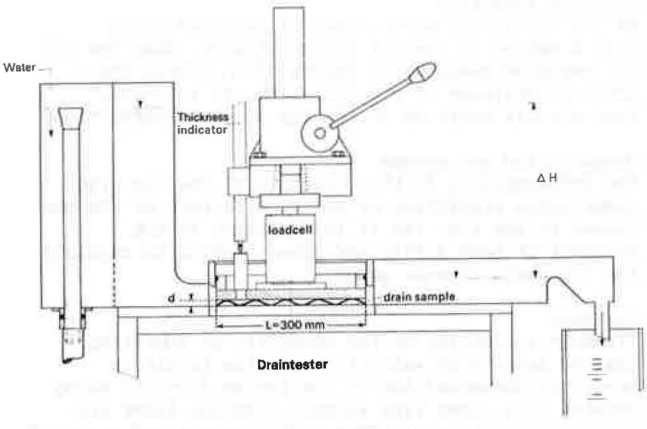


Figure 5. Apparatus for the measurement of the transmissivity of geospacers under various flat plate loads.

Transmissivity of geospacers under soil pressure

For vertical drainage of soil of low permeability, thin, narrow geospacers provided with a geotextile filter on both sides have been in use for years. The effect of soil pressure on the transmissivity of this type of geospacer has been studied (7, 8). These investigations show that transmissivity depends on the structure of the geospacer and on the type of filter envelope.

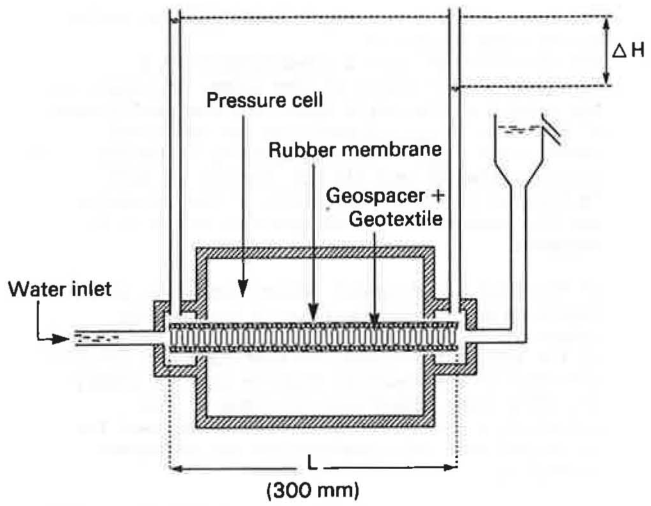
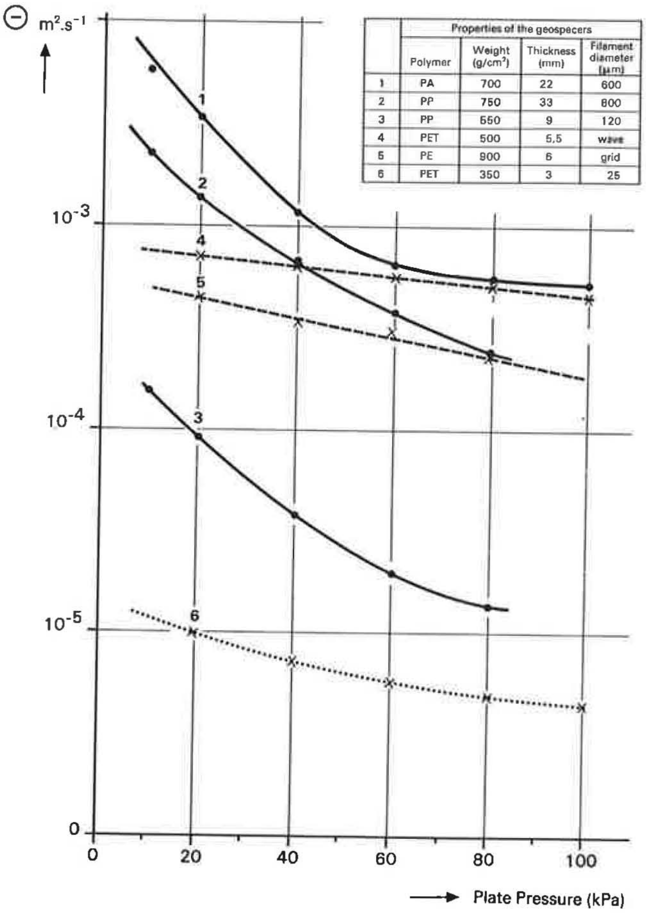


Figure 7. Apparatus for the measurement of the transmissivity of geospacers under soil pressure.

A diagram of the test apparatus used in the Netherlands is presented in Figure 7. In a closed vessel a 100mm-wide strip of drain covered with a thin unvulcanized airtight rubber membrane is compressed by means of air pressure. Transmissivity at a given hydraulic gradient can now be determined. In this apparatus the transmissivity of the same geospacer (see Figure 6, curve 1), alternatively in combination with a needle-punched and a thermally bonded polyester non-woven, was determined at a pressure of 100 kPa and a hydraulic gradient I = 1. The duration of these tests was at least 7 days. The results plotted in Figure 8 clearly demonstrate that type and weight of the geotextile filter envelope are of major importance to the geospacer's transmissivity.



	Properties of the geospecers			
	Polymer	Weight (g/cm²)	Thickness (mm)	Filament diameter (µm)
1	PA	700	22	600
2	PP	750	33	800
3	PP	550	9	120
4	PET	500	5.5	wave
5	PE	900	6	grid
6	PET	350	3	25

Figure 6. Transmissivity versus flat-plate pressure.

CONCLUSIONS

* In the storage of sludge or solid wastes, a proper use of geosynthetics can offer both technical and economic benefits.
* The additional tipping volume created by the use of such materials is an economic benefit particularly worth having.
* The initial transmissivity of a geospacer will decrease to some extent when in use. Such reduction depends on the geospacer's structure and composition.
* The nature of the geotextile bonded to a geospacer is a factor in the effective transmissivity of the composite, due to the soil pressure exerted on it.

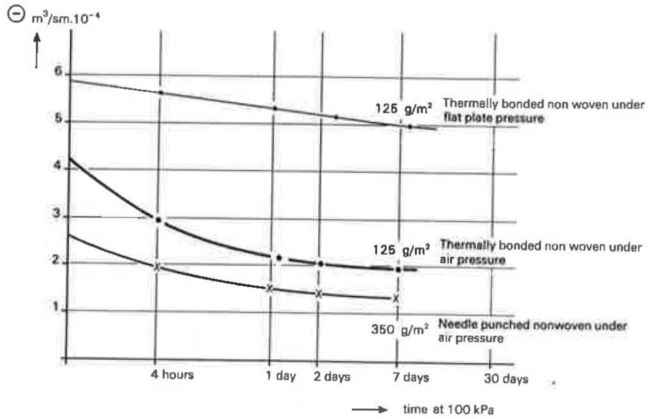


Figure 8. Transmissivity of a PA-Geospacer in combination with different non wovens.

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