Recommendations for new installation procedures of geomembranes in landfill

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ABSTRACT: For an optimal composite sealing system one has to achieve, among others, that the geomembrane lies on the mineral layer in a so called "intimate contact". This requires a practically flat placement of the geomembranes over the whole area. The problems which you have to deal with when placing the geomembranes are to get the manufacturing based shaping under control as well as the wrinkles in the geomembranes caused by sun or global radiation in order to achieve a flat surface before putting loads on the whole surface. This can be done by the "Riegelbauweise" ("Fixing Berm Construction Method" FBCM). Procedural and equipment parameters are presented.

1 INTRODUCTION

Landfills will continue to be indispensable in the foreseeable future. In order to avoid emissions the entire landfill area must be totally sealed and for this purpose cappings, slope and base liners are used. The German guidelines "TA Abfall (1991)" and "TA Siedlungsabfall (1993)" advocate that landfill cappings and base liners consist of a combination of a mineral layer covered by a geomembrane (composite liner).

The composite base liner consists of a minimum 75 cm mineral layer, as designed for a domestic waste landfill, or a mini-mum 150 cm mineral layer for a hazardous waste landfill and a geomembrane (HDPE, thickness ≥ 2.5 mm); for a capping liner a mineral layer of 50 cm and a geomembrane as above is specified.

This is supplemented by a drainage system consisting of a protective and a drainage layer. The protective layer might be composed of heavy-weight geotextiles (e.g. 3000 g/m^2) or of a combination of protective geotextile (1200 g/m^2) overlaid with sand (0/8 mm) in a thickness of 15 cm. The drainage layer usually consists of graded permeable gravel (for example 16/32 mm). The composite liner and the drainage system together make up a landfill liner system, specially for base sealings (Figure 1).

The requirements on such a liner system, climatic considerations and the resulting scheduling commitments demand a meticulously drawn up structural and operational design for the implementation of the construction work and, in particular, for the utilization of plant and machinery (Dornbusch et al. 1996).

2 PROCEDURAL AND EQUIPMENT PARAMETERS

The choice of effective plant and procedures is crucial for the technical and economic success of any building operation. This includes the scaling and performance-related coordination of the equipment line which must correspond to the particular requirements.

The various procedural steps in constructing a composite liner with a drainage system and the corresponding machinery are described in Averesch 1995 and are summarized in Figure 2 in the form of a process and an equipment line.

This paper focuses on the final procedural steps, beginning with the "Surface Treatment".

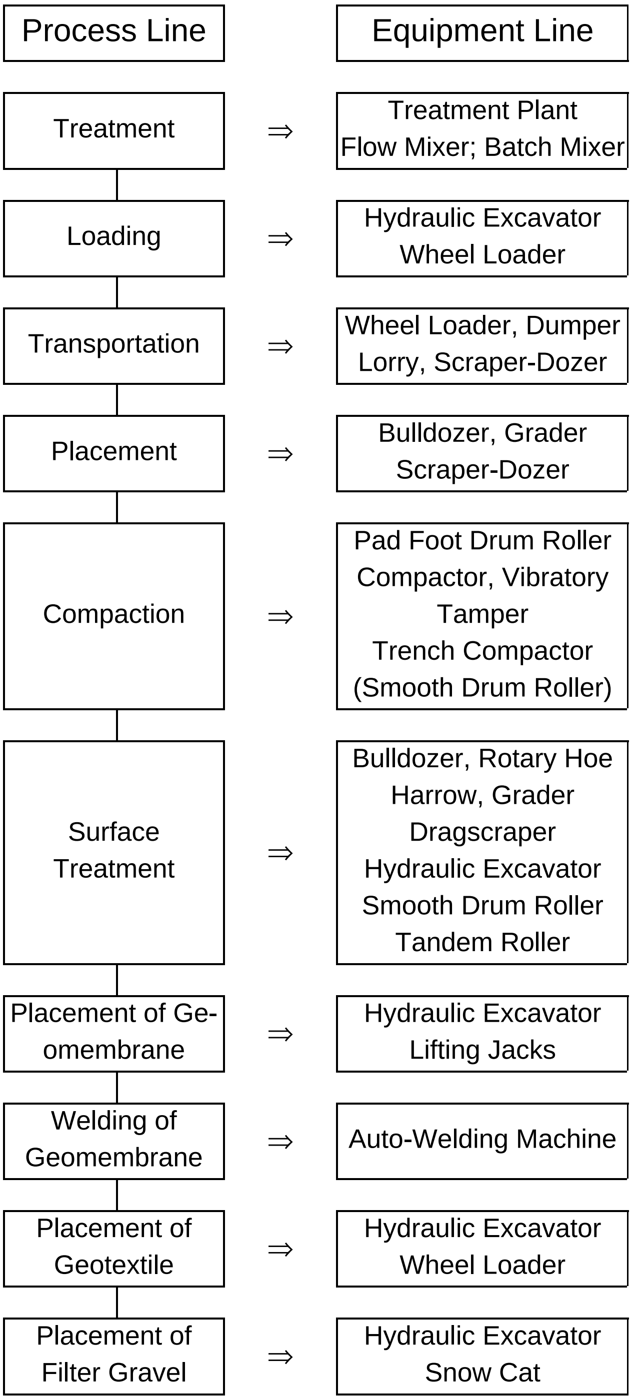

Figure 2. Process and equipment line.

3 SURFACE TREATMENT

The creation or rather the smoothing of the surface of a mineral layer thus fulfilling the precondition for laying the geomembrane properly, poses the greatest difficulties for both personnel and machines. In order to obtain the intimate contact between the mineral layer and the covering geomembrane for the composite sealing effect, the clay surface must be plane, smooth and free of foreign matter, gravel or other objects. The surface of the mineral layer should not contain single grains of more than 10 mm diameter. Such grains must be fully embedded in the clay matrix. No mineral grains with sharp edges are allowed at the surface. According to the geomembrane certification guideline set by BAM 1992 (Bundesanstalt für Materialforschung und -prüfung, Federal Institute for Materials Research and Testing), the surface of the compacted mineral layer must be absolutely clear of any abrupt changes in the surface structure. The BAM requirements allow for steps of at most 5 mm and level deviations of maximum 20 mm beneath a 4-m slat (screed) placed on top of the layer. Intolerable are deep dry-cracks, a wet or dusty-dry surface of the mineral layer during the installation of geomembrane, even when the required thickness of the mineral layer is achieved (Schicketanz 1992).

These requirements on the clay surface demand the utmost care in the implementation of the construction. This operational step can take up the same amount of time as the installation and compaction of an entire three-layer mineral liner (Averesch 1993).

Pad foot imprints cannot be leveled out by a smooth drum roller, even when using heavy models. Smoothing of the surface of a mineral layer according to the requirements demands a special procedural implementation. The following combination of techniques is favorable: the top layer must be superelevated (about the height of the pad feet), then compacted by foot drum roller. The additional millimeters will then be taken down by heavy leveling machines. For the smoothing process suitable machines are bulldozers without grousers (bogdozer model), graders or dragscrapers pulled by light tractors. The lighter the machine, the less damage will be done to the compacted clay layer, i.e. by track imprints.

Due to the possible development of shearing (which poses a threat to stability on embankments) and the subsequent breakdown in homogeneity, it is questionable to add further in-situ treatment of the earthen material by rotary hoe and harrow before the final surface treatment. However, this technique eliminates all disrupting imprints or surface roughness and a pre-smoothed surface of crumbly consistence is achieved.

A surface prepared in such a way has to be further treated by a combination of smooth rollers, consisting of heavy rollers (9-13 t) with smooth drum and ballon tyres, and light tandem rollers. Initially, one roller with smooth drum compacts the prepared surface; this can be carried out dynamically or statically. Further roughnesses, such as small hollows and wheel-prints of the rollers can only be removed using light compacting machines; any further passes using heavy rollers will create new defects. Suitable machines are tandem rollers with smooth drums and, possibly, dynamic vibration. The edges due to the shifting of the roller can be virtually avoided if the drums are displaced slightly with each transition (about 1/3 of the breadth of the drum).

4 INSTALLATION OF GEOMEMBRANES

The installation of geomembranes poses another challenge to the personnel, because they cannot drive over the clay surface with heavy machines and even inappropriate footwear might leave intolerable imprints. The heavy, rolled-up geomembrane can therefore only be brought in on and placed from on-site roads outside the construction section. Hydraulic excavators are most useful for this purpose. Spreader bars attached to the boom can pick up the geomembrane rolls from both sides of the steel cylinder core. The hydraulic excavator can access the geomembrane across the trench to the construction section from outside. The geomembrane can be unrolled either by lifting the rolls onto jacks at the construction section side and pulling down on the geomembrane manually, while maintaining a smooth underside or the entire roll with its core can be unrolled onto the construction section (with auxiliary support using ropes on embankments). Both installation techniques involve manual work.

Wheel loaders can generally be used for transporting the geomembranes on site, but because of their limited reach are less suitable than hydraulic excavators with long cantilevers or telescopic booms.

5 WELDING OF GEOMEMBRANES

The geomembranes are welded by dual track seams at the edges with auto welding machines according to the DVS-Guideline 2225, Part 4 (1996). They become plasticised by an electrically heated and controlled hot wedge, and the edges are then pressed together by a double pressure roller system and welded. The machine is entirely controlled by micro-processor. Furthermore, all the welding parameters and quality assurance data are memorized, such as welding speed, wedge temperature, welding pressure, ambient temperature, temperature of the membrane surface, date, time, machine number and installation contractor, company's logo and number of seam or site. The machines should have a serial interface so that a site's overall installation design can be monitored and depicted by PC with a graphics program (long-term documentation, database). In addition it is possible to monitor all the welds visually with the limiting values on screen simultaneously, and thus defects can be located immediately.

The need for simple landfill base design must be reiterated here as this will reduce the number of seams required.

6 INTIMATE CONTACT WITH MINERAL LAYER ("RIEGELBAUWEISE")

The required flatness of the geomembranes has often been a matter of controversy (Figure 3). The geomembrane sealing component has to be in full surface contact with the next sealing component - the mineral layer - so that the surcharges lead to an "intimate contact". It is possible to observe many different on-site techniques being applied in order to achieve this result. Despite all the problems mentioned previously, it is possible to achieve an evenly placed geomembrane on a flat surface if the personnel and site management are efficient and the installation is carried out conscientiously.

Intimate contact between the mineral layer and the geomembrane requires a flat placement of the geomembrane over the entire area. This can be achieved using the "Riegelbauweise" ("Fixing Berm Construction Method" FBCM) which has been developed and described by Schicketanz et al. 1991.

HDPE has a thermal expansion coefficient of approx. 20 times higher than, for example, steel. This expansion can be used to attain complete flatness of the geomembrane in the cooler evening hours which could never be achieved by mechanical means.

The shaping caused by the production and delivery of geomembranes as well as the waves in the geomembrane caused by sun or global radiation have to be under control in order to achieve a flat surface before the surface can be covered with the protective and drainage material.

According to the method of "Riegelbauweise" (FBCM) the geomembranes are placed following a layout-plan of placement in the morning on the prepared mineral liner surface. After about 1 hour (to adapt to the ambient temperature) the geomembranes are adjusted and stretched a little to eliminate the waves in the geomembrane condition on delivery and unrolling. Then the geomembranes are fixed with sandbags to prevent wind suction etc. After welding and testing of the seams and cleaning of the geomembrane surface, the geosynthetic protecting layer is spread.

Before it gets cooler in the evening, so called cross-"fixing-berms", consisting of protecting sand layer, drainage gravel or sandbags, are placed on the geosynthetic protecting layer at the ends of the geomembranes and at special locations (e.g. hollows, grooves, toes) to fix the geomembranes and keep them in position. The fixing berms should not exceed a distance of more than 30 to 50 m in order to avoid transverse contraction of the geomembranes. In the evening the lower temperature causes the geomembrane to become flat and subsequently the whole area can be spread with the protecting or drainage mineral layer either during the same night or in the early morning of the next day to prevent the built-up of condensed water underneath the geomembranes as well as the formation of new waves (Figure 4).

The grading of the mineral protective layer to the designed level and the placement of the drainage layer is carried out some days later during normal day time, since a direct heat effect on the geomembranes is prevented by the complete coverage and thus also no new waves can form.

The installation of geomembranes in composite liners to cover the entire surface evenly is made possible by the utilization of the physical characteristics of the geomembrane, and if the welders are experienced in their work, they can weld the geomembranes without creating any pockets in spite of the waves which invariably exist. This has been confirmed by on-site observations and is to be seen in Figure 5 to 6.

7 STRESS LOAD ANALYSIS

The highest surface temperature measured in Germany on geomembranes of 2.5 mm thickness under direct sun exposure was not more than 60°C.

Since the fixing berms are placed later in the afternoon on the already cooling geomembranes, one can consider the temperature of the fixed geomembranes to be approx. 40°C. When covering the flat geomembrane with geosynthetics and protective sand layer or filter gravel, the temperature is usually not less than 15°C. With a temperature difference of $\Delta T = 25°C$ and a coefficient of linear thermal expansion of 1.7×10^{-4}/°C the geomembrane will contain a strain of about 0.425 %. At an accepted modulus of elasticity of about 600 MPa (MDPE) the induced stress is approximately 2.55 MPa, about 15 % of the yield stress (about 17.5 MPa) of a common BAM-approved MDPE geomembrane (Seeger, S. and Mueller, W. 1996). This very low contraction stress level will additionally be reduced by stress relaxation while the geomembrane is in service. The service temperature of the geomembrane can - due to the increased leachate temperature - for the first 10 years be reckoned with up to about 35°C.

Therefore and on account of the MDPE resins used in Germany for geomembranes we see no danger of stress cracking or other kinds of failures when applying the "Riegelbauweise".

8 INSTALLATION OF PROTECTIVE LAYER AND DRAINAGE BLANKET

Analogous to the geomembrane, the BAM certified protective geotextile can only be accessed to the placement area from the outside because it is not possible to allow heavy machinery to drive on the mineral layer or on the geomembrane. Correspondingly, there exists no actual installation equipment. Hydraulic excavators with articulated or telescopic booms are suitable.

This procedural step causes further implementation problems because geomembrane and geotextile cannot be accessed by heavy machinery. Bulldozers are therefore not very suitable because of their high machine weight and shearing force which would impact on a geotextile or geomembrane; if a bulldozer is used it should be a bogdozer model with plastic tracks.

The extensive installation of filter gravel by hydraulic excavator and excavator mats is out-dated because of its inefficiency. The use of hydraulic excavators with telescopic or articulated booms is feasible. They can reach the placement area from outside or from special construction roads on the placement area which are higher than 1.0 m, that is laterally, with the help of a long cantilever (range about 12 m). Because of its excellent leveling capacities the hydraulic excavator with a telescopic boom and power leveling shovel (cutting breadth 2.5 m) has proved useful on various sites.

A competitive alternative to hydraulic excavators are snowcats. The machines, originally designed for winter sports, have a low dead weight (2-6 t) and broad tracks (2 x 1.5 m), so that only low shearing forces and ground pressures (0.040 - 0.050 kg/cm^2) are transmitted to the geotextile and geomembrane and no waviness in the geotextile or geomembrane will arise due to the installation of the protective layer. By way of comparison: a bulldozer exerts a ten times higher specific ground pressure than a snowcat.

Snowcats have proved effective on site. Even in slopes, especially if geogrids are installed, filter gravel can be pushed and placed easily and economically.

9 SUMMARY AND OUTLOOK

The choice of effective plant and procedures is crucial for a technically and economically successful construction project, along with the scaling of the equipment to correspond to requirements and the coordination of the equipment according to capacities.

Suggestions for a feasible equipment line for the construction of a composite liner incorporating a protective and a drainage system have been made above. The implementation of such a landfill liner system is highly demanding of personnel and machinery and requires the efficient implementation of construction procedures. In addition, various marginal conditions and risks as well as exacting schedule requirements increase the demands and thus exacerbate an already tense situation. The requirements which have to be met by a landfill liner system, weather factors and the resulting scheduling commitments, demand careful planning and sequential organization of the construction work and particularly in the choice of machinery. Approved effectiveness of machinery, personnel and procedures are part of the performance-related requirements.

The landfill designer has to provide simple, even, non-curved geometries for the landfill base. Landfill designers should not seek to increase landfill volume by means of complex geometries, because in this way quality is reduced and the use of effective technology is prevented.

It is possible to construct a successful and economical composite liner with intimate contact of the layers by using the "Riegelbauweise" (FBCM), if it is carried out carefully and by well experienced personnel under effective management by the contractor.

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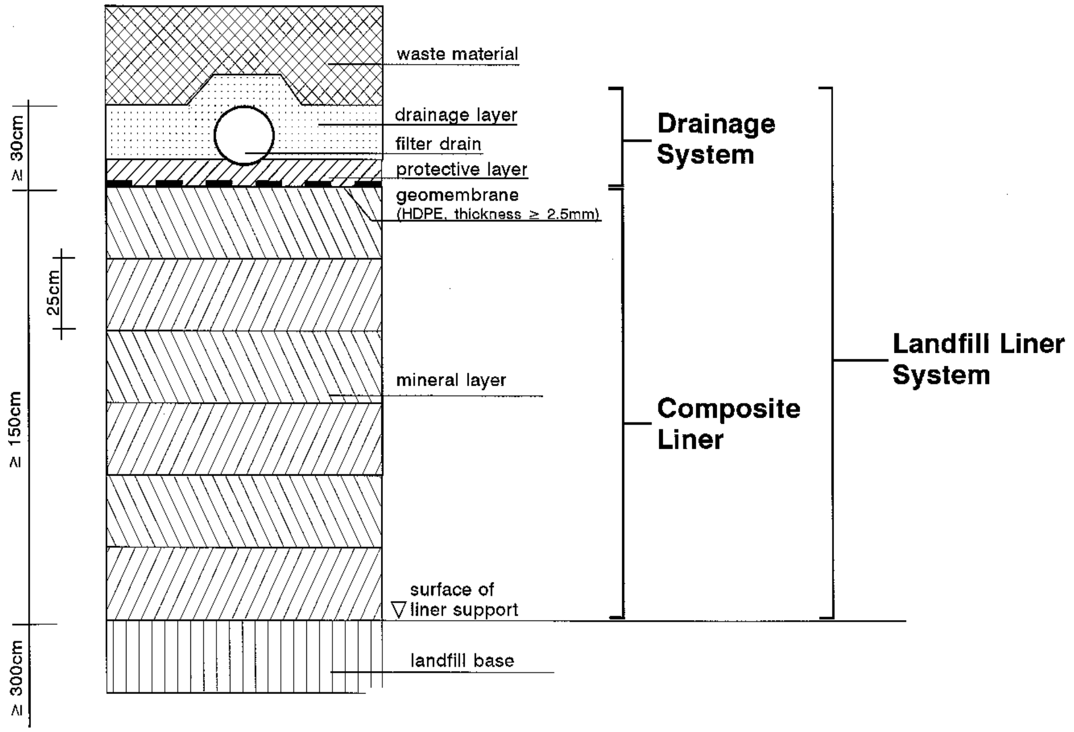


Figure 1. Composite landfill liner system for hazardous waste (Germany).

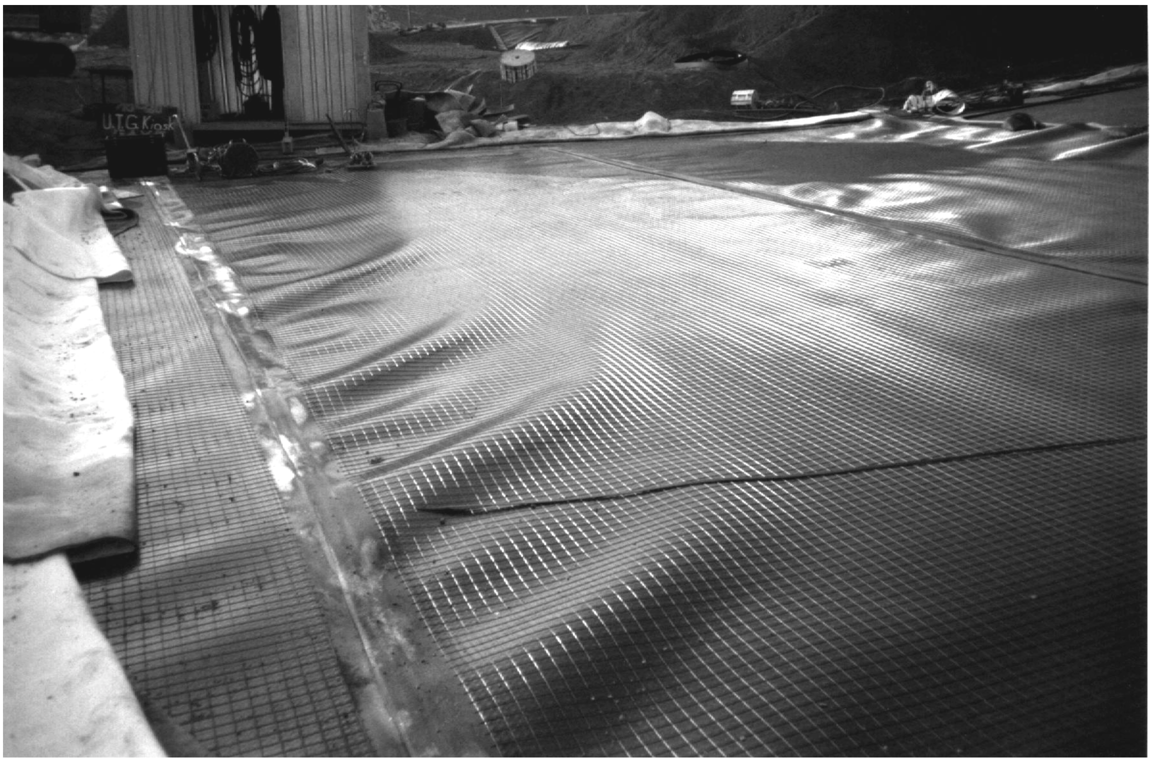
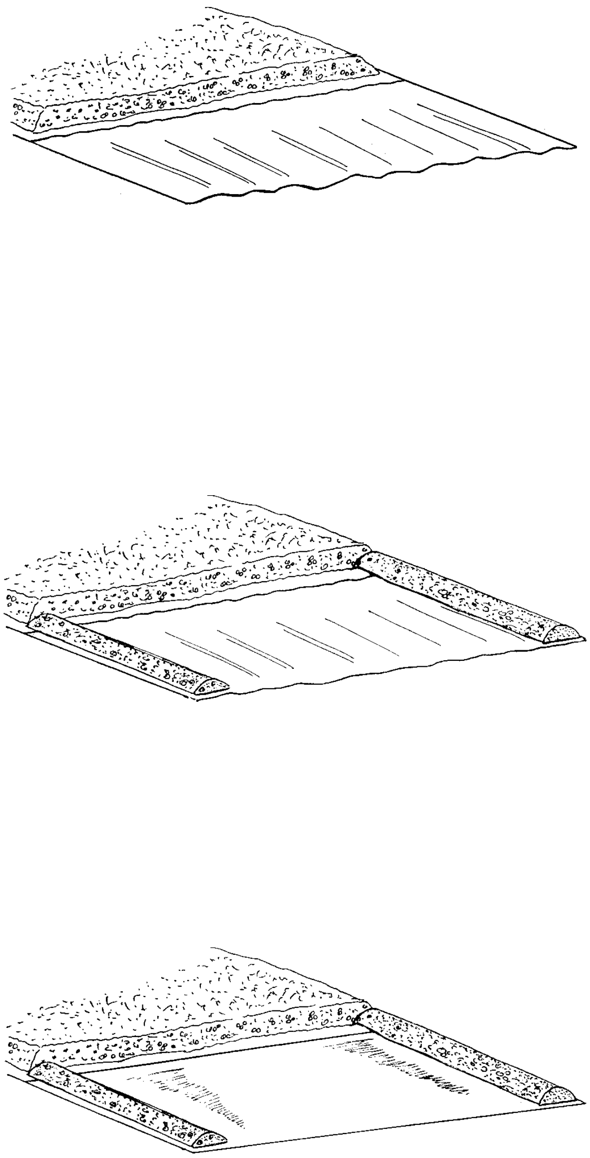


Figure 3. Example of a wavy geomembrane.



1. Spreading of the geomembrane in the morning
2. Adapting to the ambient temperature
3. Adjusting, stretching and welding during the warmest period of the day
4. Spreading of the protective geosynthetic after cleaning of the geomembranes surface
5. Setting of the "fixing berms" before ambient temperature drops
6. After flatness of the geomembranes is achieved, the protective geosynthetic shall be spread and be ballasted with the protective sand or filter gravel layer in the same evening or early in the next morning

Figure 4. Scheme of flat placement of geomembrane by "Riegelbauweise" (Fixing Berm Construction Method).

Figure 5. Example of a flat geomembrane on a landfill slope.

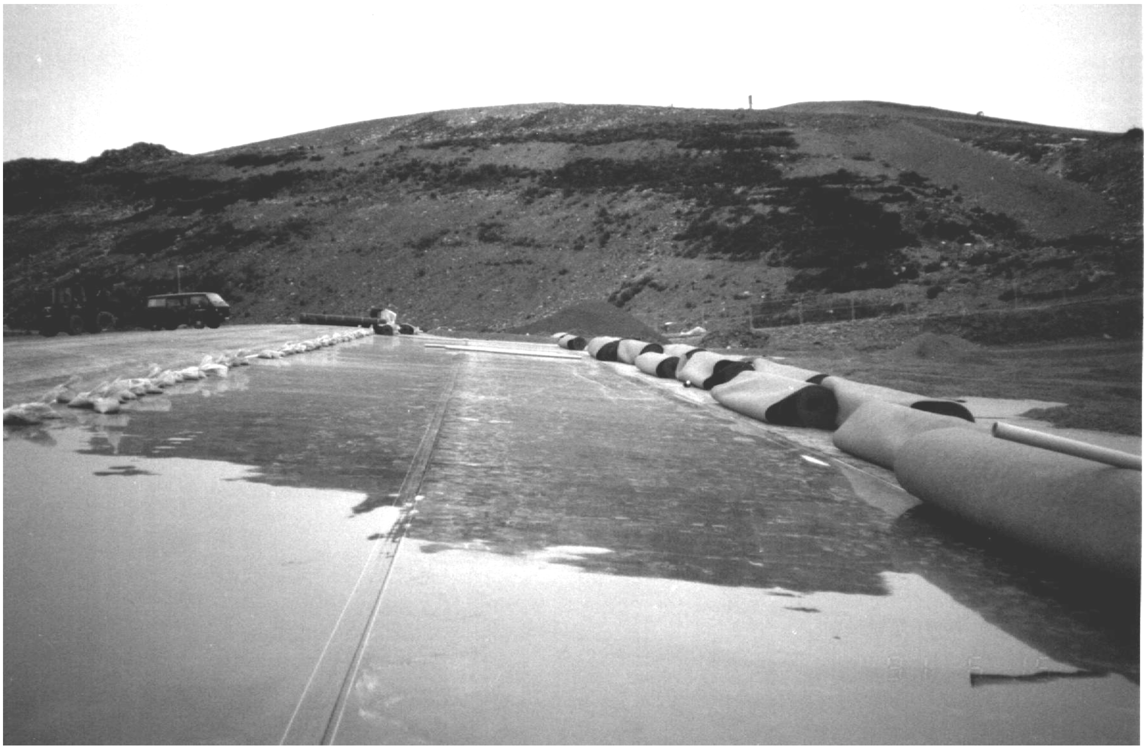


Figure 6. Example of a flat geomembrane on a landfill bottom.