

GEOSYNTHETIC CONTAINMENTS IN ENVIRONMENTAL PROTECTION⁽¹⁾

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SUMMARY

As much as we plan and implement programs for waste reduction and recycling we will continue to need waste disposal and treatment facilities such as lagoons and landfills for both hazardous and non - hazardous waste. We have a collective responsibility to ensure that the environment is protected from undesirable discharges from these facilities.

Geosynthetic materials are widely used in storage areas such as landfill leachate containment, landfill capping, reservoir liners and covers as well as for process containment for industrial and environmental applications. This paper reviews these systems particularly in relation to the extensive USA experience and looks toward those areas where we can make better use of their potential.

Geosynthetics have the capacity to overcome many of the problems experienced in the Asian region where geotechnical construction is often hampered by heavy monsoon flooding, poor soil conditions and high subsoil water levels.

1.0 INTRODUCTION

Much of the growth in use of synthetic liners in North America and Europe has been driven by regulatory frameworks which in the case of landfills demand fail-safe containment and leachate collection systems which have employed multiple layer combinations of 'natural' and synthetic materials. Because of our sometimes lesser population densities and lesser dependence on ground water for public supplies as well as an adherence to traditional disposal and dispersal methods we have not been so concerned to prevent groundwater contamination and for landfills have been willing to rely on the 'dilute and disperse' principle. In SE Asia the use of synthetic liners in waste containment has also been limited. We are now seeing an increasing concern for ground water protection and we can take advantage of others' experience with different liner systems and landfill capping systems.

In addition to their growing use in waste disposal and waste water treatment lagoons synthetic liners have been used frequently in Asia and in Australia for water reservoirs and on a more limited basis for floating reservoir covers and for covers to sewerage lagoons to enable them to function as anaerobic digesters.

2.0 LINER TYPES

Traditionally low permeability soils or clay liners have been used in earthworks to provide control of liquid migration and it is highly desirable to locate a secure landfill within a natural deposit of low permeability soil. However such sites are harder to find and the cost of material haulage and construction of clay liners has been steadily increasing. As more importance is placed on the ultimate performance of liners the attention to proper placement, compaction and quality control has served to increase the relative cost of clay liner construction.

Synthetic liners have been improving in many aspects in recent years and can now offer excellent chemical and weathering resistance with positive installation and quality assurance techniques that have lead to an increasing level of confidence.

A variety of synthetic liners such as butyl rubber, polyvinyl chloride (PVC), chlorosulphonated polyethylene (CSPE), chlorinated polyethylene (CPE), Ethylene Propylene Diene Terpolymer (EPDM) and elasticised polyolefins have been used over the years in pursuit of an ideal combination of chemical resistance, weathering performance, flexibility and weldability. Many of these involve the use of additives or polymer modifiers which help performance in some respects but detract in others. For instance modification of the basic polyethylene structure (CPE, CSPE) to improve weldability and flexibility has had a detrimental effect on the weathering and chemical resistance. Plasticisers used to provide flexibility in other polymers may dissipate or leach out over time or even encourage liner consumption by animals.

A relatively recent innovation in terms of lining technology, High Density Polyethylene (HDPE) has established itself quickly as the liner of choice for both solid and liquid waste containment. Quality HDPE liners are based on pipe grade polymer resins with less than 2% carbon black and no other additives which can dissipate over time. They are produced in wide (6 m plus) sheets and recent developments in welding technology have made their field installation reliable and efficient. HDPE provides excellent weathering and chemical resistance and a different grade of polyethylene polymer, Very Low Density Polyethylene (VLDPE) can be used when greater flexibility is desired.

3.0 LANDFILL LINERS

In Australia the use of 'natural' or synthetic liners to create secure landfills has not been widespread and has only been chosen as an option in environmentally sensitive locations or when the waste stream was seen to provide particular hazards. In recent times synthetic liners have been chosen on occasions

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as a result of a pragmatic cost/benefit examination of the alternatives and a recognition of the difficulties involved in exercising control over the materials which are directed to landfill which can result in leachates and sludges which are difficult to identify 'cocktails' of different reagents.

3.1 Henderson Landfill

The Henderson landfill liner project was the first use of a synthetic liner for a landfill in Australia. It has now had a second stage extension added and the initial project is discussed by Parker and Sadlier (1991)

3.2 Other Projects

There are a number of landfill lining projects in planning stages in several different Australian States where synthetic liners are an important part of the overall strategy. These include the Brisbane City Council waste disposal project where several of the tenderers proposed HDPE liners. The successful Rochedale Landfill proposal included a synthetic leachate collection system and a 1.5 mm HDPE liner over a 0.9 m compacted clay liner.

Engineered clay liners are still used on occasions such as the Lyndhurst (Vic) landfill which took advantage of good quality clay at site.

4.0 LANDFILL CAPS

In the case of many existing landfills and waste dumps their potential to pollute may be effectively curtailed by the provision of an effective cap to control water ingress and gas escape. Closure liners with gas collection and drainage are often an integral part of the design of new waste disposal facilities.

Landfill closures often require a somewhat different set of properties for synthetic liners than do landfill bottom liner installations. In particular, cap design usually presents the geotechnical engineer with greater concern regarding long term slope stability and accommodation of differential settlement. Friction between synthetic liners and materials contacting those liners, multiaxial elongation, and flexibility become more important for covers. And because leachate does not contact the liners and there is limited UV exposure, chemical resistance and UV exposure resistance become less important. Resistance to the components of landfill gas is, in many cases, all that is necessary.

As a result, synthetic liners with a textured surface to improve friction angles, and Very Low Density Polyethylene (VLDPE) geomembranes are becoming very attractive to geotechnical engineers. They provide considerable improvement in those areas which are important for cap installation. These materials, however, behave differently in standard index and performance testing of geomembranes, when compared with traditional polyethylene liners.

Because of their elasticity, geomembranes can accommodate shifting in the closure subgrade without losing their barrier performance. Standard clay caps, on the other hand, can lose

a great deal of barrier performance due to their absence of elasticity and the consequent development of cracks and fissures. Clay caps can also experience difficulties with variable compaction, moisture variation, and root growth.

Having no interconnected pore structure, geomembranes have no true permeability since permeability coefficients depend on Darcy's Law, a correlation for laminar flow in porous media. What little movement takes place through geomembranes is by diffusion. For water, diffusion through polyethylene is roughly a million times less than the permeability through a well compacted clay. With no effective permeability, synthetic liners thus provide excellent protection against both rainfall penetration into the closure, as well as landfill gas escaping from the closure. Good containment of landfill gas means that gas collection becomes more interesting and that vegetative covers for the closure grow much better since the gas does not contaminate the roots of the vegetation. This enhances slope stability even further and provides better erosion control for the final closure.

4.1 Very Low Density Polyethylene (VLDPE) Liners

Very Low Density Polyethylene (VLDPE) is a modern grade of polyethylene which takes advantage of the catalyst and copolymerisation manufacturing techniques of the pipe grade polyethylene's to produce a final polyethylene product of very low density. VLDPE combines many of the durability features of HDPE membranes, e.g. lack of plasticisers, low temperature resistance, carbon black stabilisation to UV light, good strength without the need for fabric reinforcement, resistance to microorganisms, insects and rodents, etc. VLDPE also has excellent natural flexibility, which is inherent, and not the result of plasticisers as is the case with most other very flexible membranes. Stress crack resistance is also excellent. And VLDPE gives good results in truncated cone puncture and multiaxial elongation tests as well. It's promise as a very durable liner for final cover of landfills is substantial.

Figure 1 shows results from tensile testing of HDPE and VLDPE liners in both smooth surface and textured form.

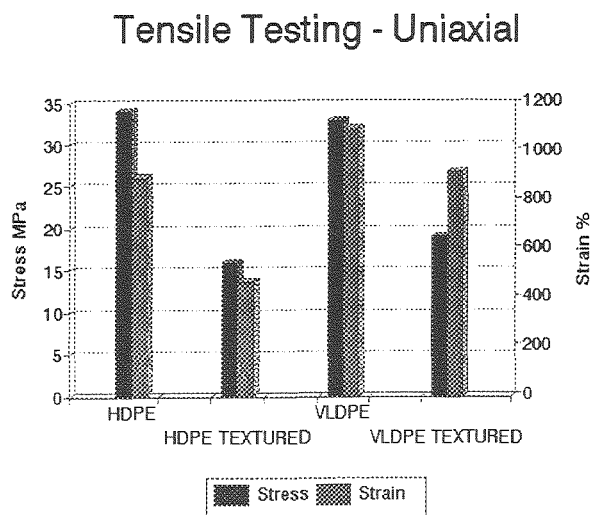


FIGURE 1.

VLDPE is also available as a textured surface geomembrane. In textured form, VLDPE combines its durability, flexibility and elongation with quite improved friction properties in contact with many different boundary materials.

4.2 Textured Polyethylene Liners

Some of the hazards that arise from the very low interface friction angle of typical smooth surface synthetic liners are discussed by Hausmann, Sadlier and Beckingsale (1992). Textured surfaces for synthetic liners have been developed in response to provide a capability for more stable interfaces.

Most textured HDPE sheet is currently made by 3-layer coextrusion, mingling the molten polyethylene in the outside textured layers with the inside smooth layer. Since the mixing occurs in the molten phase, the textured surface is fully integrated with the inside layer, which acts as the barrier to waste migration. The textured surface therefore resists abrasion and is not loosened by chemical absorption, nor physically scraped off as can happen with spray-on types of textured surfaces.

Figure 2 displays typical improvements in friction angles by direct shear for coextruded textured high density polyethylene (HDPE) liners. The friction angles indicated are approximate and will vary depending on test set up, apparatus and materials. For design purposes, actual site materials should be tested.

Friction Surface Characteristics Direct Shear

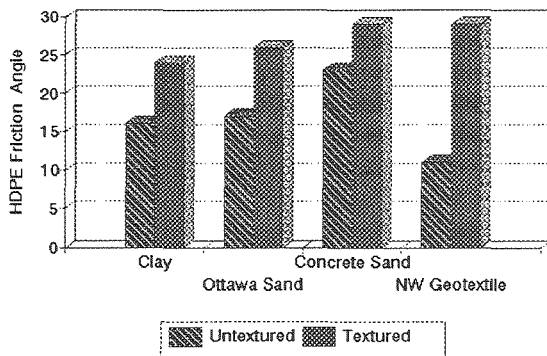


FIGURE 2.

4.3 Multiaxial Testing

Texturing of the outside layers sets up a wavy interfacial zone between outside and inside layers of the sheet which can cause edge-effects in a narrow (typically 6 mm for ASTM D 638) tensile specimen. These edge effects act as stress concentrating notches to reduce apparent tensile break performance in standard uniaxial tensile testing of textured sheet.

Recognition of this shortcoming is one reason for the development of a test procedure to examine multiaxial tension and elongation performance. This procedure is basically a large scale burst test which delivers tension to a liner sample

in 360 degrees, instead of a uniaxial one-dimensional direction. A commonly used test method for multiaxial elongation is GRI GM4. (GRI is the Geosynthetic Research Institute, Philadelphia, USA.)

Multiaxial Stress Testing - Rupture

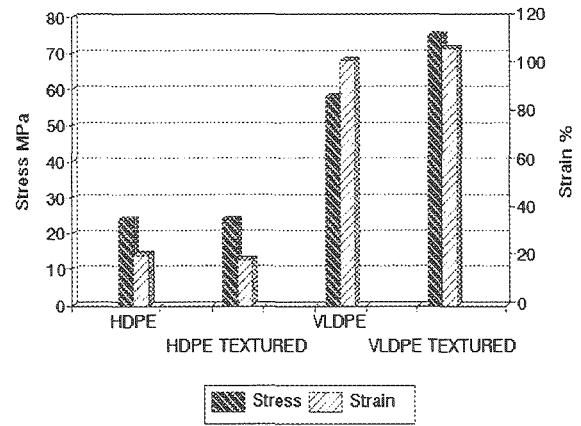


FIGURE 3.

Figure 3 compares performance of textured HDPE and VLDPE to standard smooth HDPE and VLDPE in multiaxial elongation testing.

The beauty of multiaxial elongation testing is that it eliminates edge-effects present in uniaxial tensile testing. There are simply no edges in the test sample to influence results when correlating them to the large scales in the field. For this reason as well as for the fact that tension forces in the field are very often multiaxial, multiaxial elongation testing is considered a "performance" test, more suitable for design purposes than the uniaxial tensile test.

Because edge-effect bias is eliminated, the multiaxial elongation test offers a better test to evaluate true performance of textured liners.

4.4 Gosnells Landfill Cap

This facility is in the City of Gosnells near Perth W.A. and it started life as a industrial liquid waste collection pit and has since been topped up with domestic waste prior to the installation of a HDPE and soil composite cover. Details are discussed by Parker and Sadlier (1991).

Another interesting capping application is the Kingston (Brisbane) contaminated site clean-up which used a geosynthetic liner system as part of a composite capping strategy for the more severely contaminated area. This capping project is discussed in detail by Sadlier, Fehervary and Marsh (1992)

5.0 GEOTEXTILE USE WITH SYNTHETIC LINERS

There are numerous potential applications of geotextile fabrics with geomembranes due mainly to their polymeric compatibility and the filtration, drainage and mechanical protection capabilities of the geotextiles. Common uses include filter protection of drainage layers, friction control at interfaces, temporary covering, puncture protection and fluid transmission. The last two are discussed here.

5.1 Geomembrane Puncture Protection

Impermeable geomembrane liners used in containment systems are relatively thin and can be damaged easily, both during installation of the liner system as well as after completion of construction due to loads imparted by waste and other cover materials. Experience has shown that needlepunched nonwoven geotextiles can play an important role in successful geomembrane installations and long term performance by acting as a cushion to prevent puncture damage to the geomembrane.

HDPE LINER PUNCTURE RESISTANCE

Pyramid Puncture Test (modified CBR)

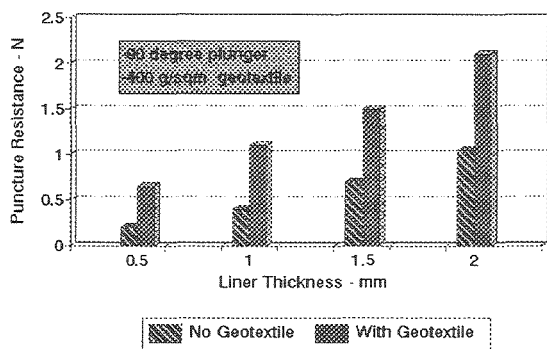


FIGURE 4.

Geotextiles can be placed below geomembranes to resist puncture and wear due to abrasion caused by sharp edged rocks in the subgrade and above the geomembrane to resist puncture by drainage aggregate, waste materials or other solids. Similarly, during intermittent covers and final closures, geotextiles can be placed below the geomembrane to reduce risk of damage by sharp objects in landfills and above the geomembrane to prevent damage during installation of soil cover. In order to provide sufficient protection against puncturing of a thin membrane, only those types of thick needlepunched nonwoven geotextiles with more than 200 g/sqm weight per unit area are recommended.

Results from testing carried out by Puhlinger are illustrated in Figure 4. The procedure employed a 90° included angle pyramid plunger in a CBR rig with a metal plate under the geomembrane. Various thicknesses of HDPE were tested with and without different grades of non-woven continuous filament polypropylene geotextile. In this illustration the geotextile has a unit mass of 400 g/sqm and it is interesting to note that the effective puncture resistance of a 2mm liner can be provided by a 1mm liner and geotextile at considerable cost saving.

5.2 Liquid and Air Transmission

Relatively thick needle punched nonwoven geotextiles have a three dimensional fibre structure and high percentage of air voids which allows radial free flow of liquids and gases in the plane of the fabric. As such, they can be used as a drainage layer in the following situations which are presented as examples:

- Between the two membranes of a double lining system, in order to drain any leakage that may occur through the primary (top) liner.
- Between membrane and soil, or between membrane and waste material to drain any slope, waste seepage or groundwater. (Moisture between a geomembrane and underlying soil can significantly decrease the interface friction angle.)
- Beneath a geomembrane liner in a liquid containment system to divert gases from beneath the system that can accumulate due to organics in the underlying soils.
- Beneath intermittent and final landfill cover systems over waste disposals to act as gas transmission media and divert gases to collection systems.

5.2.1 Water Transmission

Design and selection of the geotextile will depend on the magnitude of anticipated seepage, the normal stress anticipated over the geotextile, and the geotextile characteristics including thickness, weight per unit area, and fibre type. Different fibre shapes, needling lubricants and fibre lengths can all affect the surface tension and flow characteristics so product specific tests are essential. Transmissivity responses of needlepunched nonwoven geotextiles as a function of normal stress are readily available and calculations based on Darcy's formula can be used to determine if flow capacity is sufficient.

In many cases the anticipated flows are not large and are difficult to quantify with confidence but control is still critical. Evaluation of suitability is often based on order of magnitude correlations.

If greater transmissivity is required than can be provided by heavyweight needlepunched nonwoven geotextiles, special layered systems such as geonets must be installed.

5.2.2 Gas Transport

In this application, the same design considerations and calculation methods as for water transmission can be used. Because of the high porosity of needlepunched nonwoven geotextiles (90% air voids in an uncompressed state), gas transmissivity is usually sufficient, even under very high applied normal loading. Under comparable conditions, gas transmissivity is approximately two orders of magnitude greater than water transmissivity (Koerner, et al., 1984). Therefore, it is sufficient to base the design on water

transmissivity, since even with a high water content in the geotextile there will be sufficient gas transmissivity available for the venting of gases.

6.0 LIQUID STORAGE LINERS AND COVERS

Synthetic liners are well known in liquid containment around Australia and in Asia but there is potential to make better use of synthetic covers for protection of water supplies from pollution and evaporation losses.

Golf courses and similar developments have made use of thin PVC liners for water containment and this choice has been made on the basis of minimising capital cost at the expense of service life unless a soil cover is also used. Dissatisfaction with long term performance of PVC liners in such pondages has resulted in a trend towards thin HDPE and VLDPE liners which are cost effective and offer better exposure performance.

Reservoir floating covers in synthetic liner material provide the potential to control pollution (e.g. from birds) and evaporation losses at a significant cost advantage over conventional roofing. If the water level is to fluctuate constantly then a liner material with excellent flexibility is required but this can be in conflict with the other requirements of excellent UV weathering performance and weldability even after exposure. A rational approach to this problem is to use different combinations of materials to maximise flexibility in unexposed portions and to maximise UV weathering performance in exposed portions.

7.0 ANAEROBIC LAGOONS

Anaerobic digestion is a very effective method for biological treatment of sewerage sludges and floating covers in HDPE can sustain anaerobic activity in large scale lagoons with odour control and methane gas collection as secondary benefits. This type of cover can be installed over existing aerobic lagoons to give the twin benefits of anaerobic digestion and odour control. Many industrial complexes find this concept attractive as do municipal sewerage authorities considering the implications of urban sprawl taking built-up areas closer to existing aerobic lagoons.

Normally there is very little fluctuation in level in these lagoons and the gas is collected under a vacuum so that chemical resistance, UV weathering performance, and weldability are at a premium over flexibility, making HDPE the normal choice of cover material. The cover is usually attached to a concrete edge anchor beam or restrained by a backfilled anchor trench and HDPE pipes are used for the gas connections. Floating end details are also possible and this allows the possibility of partial covering of existing lagoons.

There are several smaller examples of this use of a synthetic liner digester lagoon cover around Australia including digesters for food processing plants at Manjimup in W.A. and Bendigo in Victoria. Very recently Melbourne Water have installed the world's largest floating HDPE membrane digester cover over an active anaerobic pot at their Werribee Sewerage Farm.

An indication of the potential of the concept is the Sonoco paper mill digester in South Carolina USA which measures

290 m by 120 m (35,000 sqm) and is made from 2.5 mm HDPE. It removes 60-80% of the effluent BOD and produces approximately 10 cu.m/min. of bio-gas of which over 50% is methane which is used for its heating value.

8.0 CONCLUSIONS

Synthetic membrane liners have been seen in various applications around the Asia Pacific Region and most senior engineering practitioners will have had at least some passing experience with them.

With the increasing demand from the community for control of leachate formation and possible escape from waste disposal facilities there will be many opportunities to use synthetic liners to help protect our environment. There will also be opportunities for applications in water storage and particularly interesting possibilities in floating covers for digester lagoons for effluent water treatment.

As with many newer materials, success will come from recognition of the attributes and shortcomings of synthetic liners and employing them within their capabilities with appropriate quality control and checking measures.

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