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GEOMEMBRANE USEAGE FOR SPILL CONTAINMENT IN PETROLEUM PRODUCT STORAGE AREAS

L'EMPLOI DE GEOMEMBRANES DANS LES BASSINS DE RETENSION DANS LES ZONES DE STOCKAGE DE PRODUITS PETROLIERS

DER EINSATZ VON GEOMEMBRANEN BEI ÜBERLAUFBECKEN VON ERDÖLTANKS

Bulk storage facilities for petroleum products have reached massive proportions, whereby the tanks containing over hundreds of thousands of barrels (millions of litres) have become commonplace. The need for proper spill retention therefore becomes a critical component of the facility. Traditional methods consisting of earth berming are still widely practiced, however there is a need to provide fail-safe protection of the environment against pollution. This paper outlines the practices employed for spill retention around petroleum product tankage. The practice of using geomembranes exclusively for this purpose is proposed.

Umfangreiche Einrichtungen für Erdöl Produkt Lagerung haben massive Proportionen angenommen, wobei die Tankanlagen alltäglich über Millionen von Litern aufspeichern. Der Bedarf für geeignete Überlauf Verhaltung wird dafür ein kritischer Bestandteil der Einrichtung. Herkömmliche Verfahren bestanden aus Erd Deiche und werden immer noch weitgehend gebraucht, jedoch ein Bedarf für einen unfehlbaren Schutz gegen Erd Verschmutzung nötig ist. Diese Abhandlung gibt einen Überblick wie das Verfahren für Überlauf Verhaltung um Erdöl Produkt Tankanlagen angewendet wird. Der Gebrauch von Geomembranen ist ausschliesslich aus diesen Grund vorgeschlagen.

INTRODUCTION

Most regulatory jurisdictions require some form of dyking system around petroleum product storage areas. This is usually effected by the construction of berms around single tanks or groups of tanks which can contain the entire contents of the tankage in the case of a spill. The berms are sized so as to contain 110% of the capacity of the tank. In the case of multiple tanks, the retention capacity should be equal to the capacity of the largest tank, plus 10% of the aggregate capacity of all other tanks within the enclosure. The berms are normally constructed using locally excavated clay materials, in order to provide a measure of impermeability, necessary to contain the spill until it can be cleaned up. Vegetative growth, which could create preferential paths for liquid passage in the form of a secondary structure, and the normally resultant desiccation, is often inhibited by regular applications of waste product onto the clay berms (Figure 1).

Several factors can contribute to a situation in which this form of containment is unsatisfactory. In many locations, notably the far north where virtually all power and heat originates from petroleum product fueled sources, there is not a sufficient clay resource to construct the berms. Similarly, cold regions climates preclude any assumption of adequate impermeability of clay soils, when available.

The growing awareness and concern with regard to environmental damage has eventually led to more rigorous requirements for this type of facility, although for the most part, these are applied mainly to new facilities, due to the prohibitive cost of renovating the vast number of existing storage areas. It is now good standard practice to provide a geomembrane liner for the dyked enclosures, to ensure effective containment. In some cases, however, geomembranes are being added to facilities which have been in operation for some time, due to a recognition that the environmental consequences of spills polluting nearby water courses or groundwater are unacceptable.

SITING OF STORAGE FACILITIES

Although the selection of appropriate means of preventing the pollution of the environment in the case of a spill is the primary topic of this paper, it is important that the designer of such facilities employ whatever means at his disposal, in order to mitigate the effects of leakage from the containment, recognizing that these facilities cannot realistically be deemed to be fail-safe, especially in isolated areas.

Site selection for petroleum product storage facilities is naturally constrained by the demand parameters which call for these structures in the first place. The site selection criteria for storage facilities in isolated, northern (arctic) areas is of particular interest as the response to a spill may be slow due to inaccessibility, and the fact that the environment in the arctic is fragile to an extent far beyond 'normal' for moderate climates.

Figure 1: Conventional Berm Containment

Site selection criteria which must be considered to be base-line minimal include the following:

- a complete review of the topography, geology, geotechnical conditions, hydrology, and climate of the area;
- a surface, visual examination of the proposed sites to qualitatively assess the surficial drainage patterns, landforms, permafrost features, all of which will affect the performance of any structures;
- a detailed subsurface investigation, including the examination and quantification of geotechnical soil properties, groundwater, ground ice content, and ground temperature conditions.

The final site selection will be based on an optimization of the combination of site conditions, site location dictated by the function of the facility, and cost feasibility of the project. In many instances in isolated areas, the latter consideration cannot be allowed to govern.

CONTAINMENT MEASURES

Although traditional practice has been to utilize clay berms, usually with no special treatment of surficial layers, for the containment of the spilled fluids, geomembranes are a more positive measure, with regard to prevention of the escape of these materials from this containment.

There are two general requirements for these facilities: containment, to prevent the spread of a spill over an extensive area; and retention, which represents the necessity of retaining the fluids until such time as they can be recovered. In the system which is installed in these facilities, the berms can serve alone as adequate containment, confining the spread of the spill to a limited area around the storage tanks. Two situations exist, however, in which the containment of the spill is not sufficient.

These include:

- areas in which a sufficient quantity of suitable clay materials with which the berms can be built, are not available, necessitating the use of relatively permeable granular soils;

- facilities for which the response time cannot be guaranteed, to prevent the migration of the spill through the berms and subsequently into environmentally sensitive or fragile areas.

As noted previously, the latter is quite possible in isolated northern locations, and remotely controlled facilities. In each of these situations, there should be no relaxation of the requirement for an impervious liner system. This criterion can most effectively be met utilizing flexible membrane liner systems, now generically known as geomembranes.

GEOMEMBRANE SELECTION

Geomembranes have been used very extensively for the retention component function in petroleum product storage areaas for many years. Practice today in many jurisdictions requires the use of geomembranes without alternate, and in fact many facilities have been modified from originally constructed soil liners, as environmental awareness increases and the regulatory requirements are upgraded.

The selection criteria for geomembranes for this purpose are not specifically different from those employed in other applications. From an environmental viewpoint, geomembranes must be capable of resisting exposure to the contained fluids for both short and long terms. In addition, they must retain their physical, mechanical, and chemical properties in long term and cycled exposure to extremes in temperatures. The climate in the north is one of the most extreme on the planet, with air temperatures in winter and summer capable of attaining -70°C and 30°C, respectively.

Table 1 illustrates typical selection requirements which must be considered for these applications.

TABLE 1: SELECTION REQUIREMENTS

PROPERTY	TEST OR GUIDELINE
Resistance to deterioration or change when exposed to the fluid to be retained.	EPA 9090
Adequate mechanical properties.	ASTM D638, D751, D882, D1004, D2240, FTMS 101C Mtd. 2065.
Long term durability.	ASTM D1149, D1204, D1693.
Cold weather flexibility.	ASTM D1790, D2136.
Panel size and field seamability.	Varies with polymer and installer.
Repairability.	varies with polymer, manufacturer, and installer.

HYDROCARBON RESISTANCE

As with any application utilizing polymeric materials, the resistance to change of the material properties or behaviour under prolonged and even short term exposure to the fluids to be contained is the critical factor affecting selection. The most common deterioration of geomembranes when exposed to fluids with which they are incompatible is swelling, which will tend to decrease the strength of the geomembrane, while increasing the permeability.

MECHANICAL PROPERTIES

In most instances, the loads and stresses, which are applied to the geomembrane in this particular situation in an operating mode, are not severe. In general, the most critical stresses will be applied during the handling and installation stages. The expansion and contraction of some geomembranes in response to moderate and severe temperature variations can greatly affect their long term performance. In arctic and even subarctic environments, daily temperature variations of 20°C to 30°C are relatively common. Fatigue related failures of liners due to the continual expansion and contraction are becoming apparent.

LONG TERM DURABILITY

One of the peculiarities of the geomembrane used for spill containment, is the fact that it is used with the hope that it will never have to serve the purpose for which it is intended. In short, we hope that a spill will never occur. In fact, such is precisely the case with many of the existing facilities of this type throughout the world. From a design point of view, the engineer is therefore forced to endure the "we didn't need it anyway" mentality.

Nevertheless, this highlights another consideration, that being that the conditions to which the geomembrane will be exposed for the vast majority of its useful life are not those for which it is specifically designed. The durability-related properties of the liner are therefore equally as important, to ensure that the geomembrane is capable of carrying out its function when it is called upon, which could easily be many years after installation. If the liner cannot endure the environment in which it is placed, it could very possibly not perform at the time of a spill, and disastrous environmental consequences result from a situation which is otherwise believed to be secure.

COLD WEATHER FLEXIBILITY

This naturally relates to another concern with regard to handling, that being the cold weather flexibility. Due to the logistical constraints of operating in the isolated north, less than ideal handling and installation conditions often prevail. Folded panels of geomembranes which are convenient for shipping purposes may be catastrophic as the panels are unfolded in cold temperatures, and damage in the form of cracking occurs. It would then be necessary to find polymers that exhibit better flexibility and cold temperature resistance, if the constraints on the handling of the materials and timing of the installation preclude alternative shipping modes.

PANEL SIZE AND SEAMABILITY

The previous consideration therefore leads to another constraint which often arises with regard to geomembranes, that being the optimization of the size of the panels, and the relative ease of attaining a good field seam under the greatest range of field conditions. In the case of liners for spill containment in northern communities, the tanks are frequently of relatively modest size, and field seaming requirements can be minimized. On the other hand, some areas are not readily accessible at all in winter, and fuel storage requirements for such communities may be out of proportion to the size of equipment that they feed. A six month storage capacity is not unreasonable in such an instance.

Field seaming can be monitored by a proper quality assurance program, which should be an integral part of any geomembrane installation, in any event. The ability of seaming to be carried out in the temperatures which are apt to be encountered is therefore important, as it will vary from one polymer to another.

REPAIRABILITY

Many polymeric materials do not lend themselves to patching, after even modest amounts of exposure to weathering conditions. As high quality materials are frequently unavailable in these areas for use in covering liners, exposed membranes are usually used. Another reason is that a soil cover could hamper cleanup of any spill contained within the system. The fact that these geomembranes are exposed makes them vulnerable to damage from vehicular traffic and any operations around the tank. Damage is therefore something which can occur even in cases where extra care is intended, since the discipline of care is frequently eroded when prolonged periods of normal activity occur.

Table 2 summarizes some of the relative considerations for geomembrane selection for the more common materials in use, as discussed above (from Wallace and Eigenbrod, 1983).

LINER CONFIGURATION

The configuration of the geomembrane liner for the spill containment enclosures around petroleum product storage tanks will depend on several factors, including the geometry of the existing facility, particularly when the geomembrane is being added after construction of the tankage. Figure 2 illustrates such an installation, whereby the liner needs to conform to the existing design. Needless to say, there are a large number of configurations which can arise, depending upon the degree to which operation of the tanks can be interrupted, if at all. Projections through the liner are undesirable, but, if necessary, should be kept to a minimum. Mechanical connections to the tank wall are also generally undesirable, expecially in cold climates, as the severe temperature differentials on the geomembrane can cause unwanted stresses within the joint, which could affect the seal.

The ability to incorporate the geomembrane system into the original facility results in a much more reliable system, although the need to be aware of other factors becomes more acute. The extension of the liner below the entire enclosure, including the tank (see Figure 3) results in greater constraints when selecting the geomembrane. Tank settlement, and the liner necessitate some additional measures. Either the settlements must be minimized to the tolerances imposed by the liner properties, or the geomembrane cannot be placed below the tank. Elimination of the mechanical connection is desirable, so an appropriate selection process should be followed in order to accommodate the liner below the tank, if possible. This naturally relates back to the geotechnical component of the design, and the compressibility of the underlying soil.

TABLE 2: SUITABILITY CRITERIA FOR GEOMEMBRANES

POLYMER	HYDROCARBON RESISTANCE	MECHANICAL PROPERTIES	LONG TERM DURABILITY	COLD WEATHER FLEXIBILITY	REPAIRABILITY
Oil Resistant Polyvinyl Chloride (Oil PVC)	Excellent	Excellent	Good	Poor	Good
Chlorosulfonated polyethylene (Hypalon)	Poor	Good (reinforced)	Fair	Good	Fair
High Density Polyethylene (HDPE)	Good	Excellent	Excellent	Good	Good
Butyl Rubber	Poor	Good	Good	Good	Poor
Chlorinated polyethylene (CPE)	Poor	Good	Good	Fair	Fair

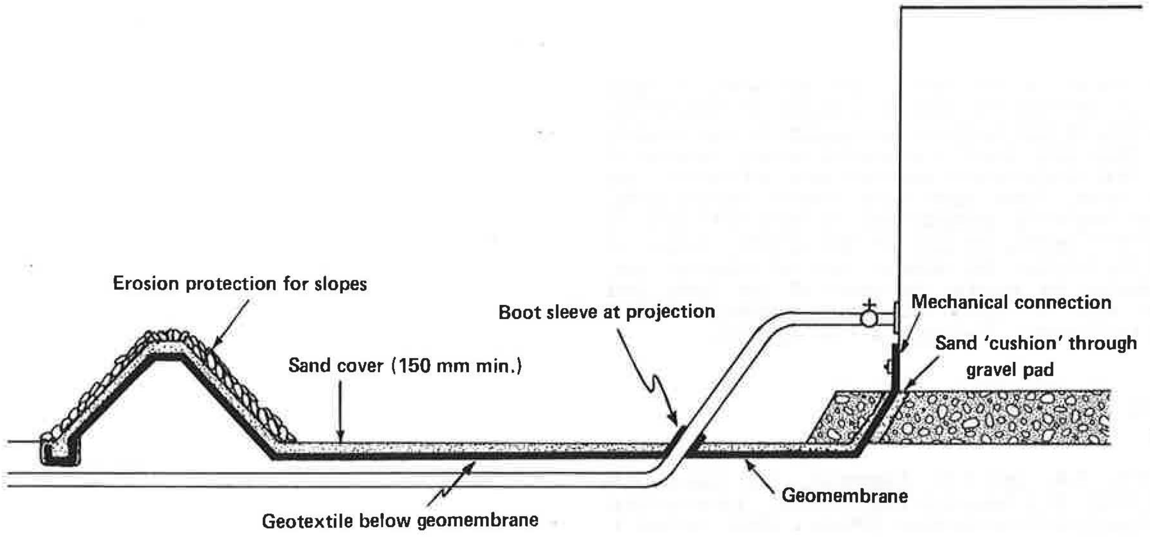

Figure 2: Geomembrane Added to an Existing Facility

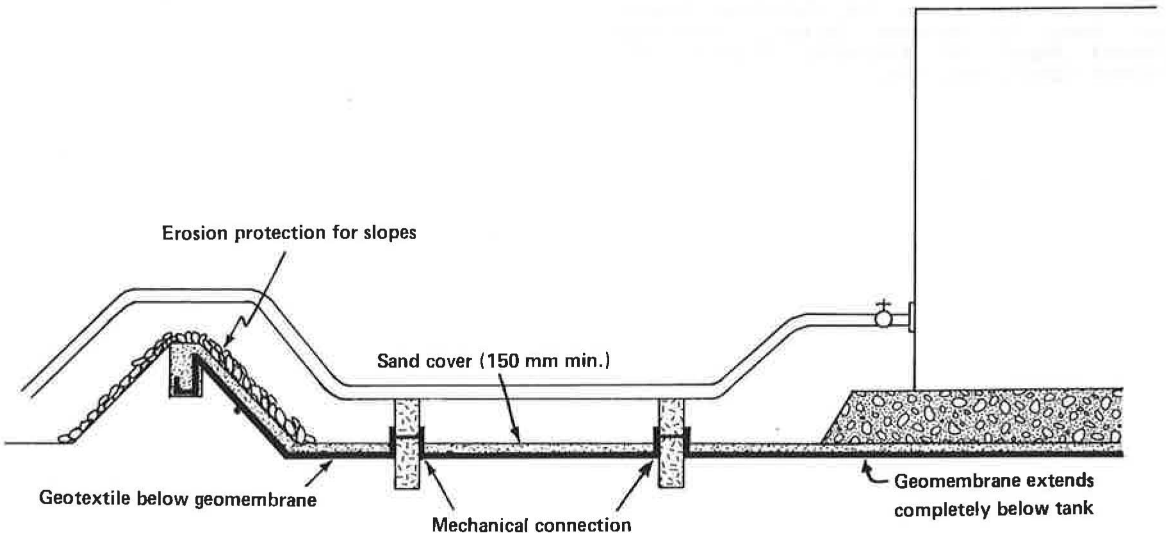

Figure 3: Geomembrane Incorporated into a New Facility'

In Figure 3, the piping associated with the tankage is all above grade, resulting in no projections through the liner. In such a case, the liner can be preserved as a continuous barrier, and repairs to piping which may be required are possible without the destruction of the liner. The price which must naturally be paid is the loss of vehicular accessiblity around the tanks, and design must consider this when these piles are being located.

The simplified configurations illustrated in Figures 2 and 3 are presented primarily to illustrate some of the things which must be considered when designing these facilities. No generalities with regard to selection of geomembranes are presented, as the constraints of the project which arise from site cnoditions, climate, and the tanks themselves will determine to a greater degree, which characteristics are required for the liner.

CLOSURE

Newer facilities in the arctic are now being designed with the geomembrane included as a matter of regulation. The fragility of the northern environment is more readily apparent than more heavily populated areas, because of the fact that disturbances are much more noticeable, and in some cases, have much more severe consequences. Regulation requiring geomembranes is more difficult in the populated areas, because of the greater number of affected facilities, the greater ease of cleanup, and, unfortunately, the greater influence of the lobby that does not want to spend the money, particularly on existing facilities. They must all be overcome.

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