THE USE OF GEOTEXTILES AND GEOMEMBRANES IN HIGHWAY CONSTRUCTION

by

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ABSTRACT

This paper provides an overview of the use of geotextiles and geomembranes by Alberta Transportation and Utilities in highway grade construction throughout the Province of Alberta. Geotextiles and geomembranes are commonly used today by many highway agencies in the resolution of problems associated with highway construction.

Alberta Transportation and Utilities began using geotextiles in 1977 as reinforcement for muskegs and soft ground problem areas. Since then, the use of geotextiles has increased considerably. From about 1985 to 1990, 1.5 million square metres of geotextiles, geomembranes and geocomposites have been used in a variety of applications related to the functions of filtration, drainage, reinforcement, separation, and moisture barrier.

The present trend is towards a declining use of woven geotextiles and increasing use of non-woven geotextiles and geocomposites. This trend is consistent with a decrease in new construction activities and increased maintenance activities related to environmental concerns such a roadside ditch erosion and siltation of sensitive water bodies.

Keywords: geotextiles, geomembranes, geocomposites, geotechnical design, highway construction, erosion control.

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INTRODUCTION

Alberta Transportation and Utilities began utilizing geotextiles in highway construction around 1977 as reinforcement for muskegs and soft ground areas. When geotextiles were introduced to the Department, non-woven geotextiles were fashionable in Alberta and were generally cheaper than their woven counterpart. In addition, the non-woven geotextile was recommended for filtration, drainage, separation and reinforcement.

As time progressed, woven geotextiles were gradually adopted for distinct reinforcement applications in muskeg and soft ground areas. This application generally kept abreast with published research findings and trials and observations made by Alberta Transportation and Utilities from around 1986 (Diyaljee, 1988).

Geomembranes, on the other hand, were only utilized within the last 5 to 6 years and are now frequently utilized either singly or in combination with geotextiles. The combined use of geotextiles and geomembranes has been applied in subsurface drainage where directional flow of groundwater is required.

The use of geotextiles and geomembranes has increased considerably since their introduction. Today, these materials are commonly accepted for use in construction and maintenance. Environmental considerations in highway construction have also added to the importance of geotextiles and geomembranes in respect to mitigative measures for erosion control.

In the last 3 years, there has been a growing concern about the effective and efficient use of geotextiles and geomembranes in highway construction throughout the Province of Alberta. As a result, the Geotechnical Section of the Department has been given the mandate to ensure that these products are properly utilized.

This mandate has resulted in the development of generic specifications and stipulation of material types for uses that do not require detailed design.

The purpose of this paper is to overview the use made by Alberta Transportation and Utilities of geotextiles and geomembranes in highway grade construction.

FILTRATION

SUBSURFACE DRAINS

Filtration is perhaps the most popular function for which geotextiles are utilized by Alberta Transportation and Utilities. The traditional subsurface drains with or without perforated pipes and containing free draining granular material have now taken on a different appearance with the use of non-woven geotextiles, Fig.1.

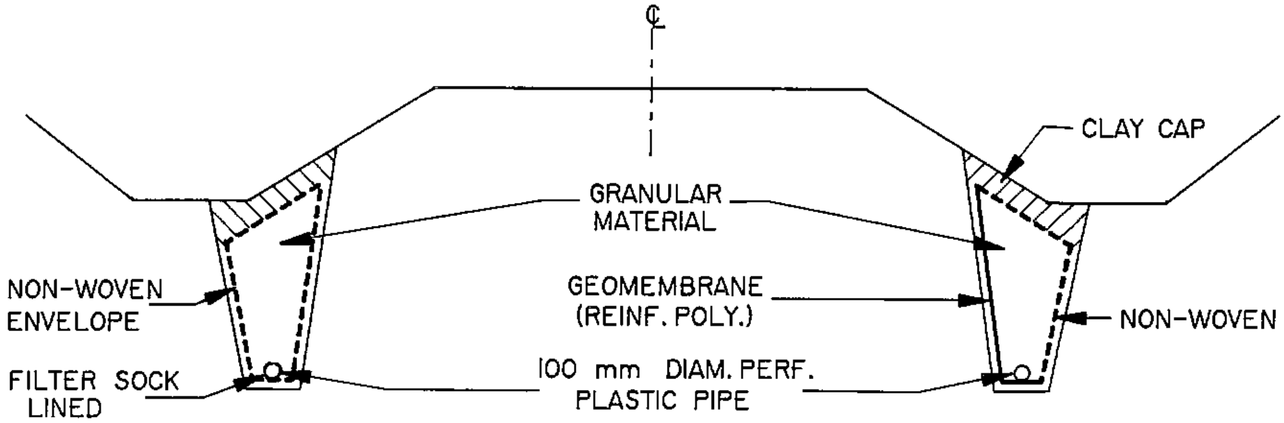

Fig. 1. Use of Non-Woven Geoxtile in Subsurface Drains.

Non-woven geotextile is used as a filter sock around perforated pipes which may be corrugated plastic or corrugated steel. The intent of the filter sock is to prevent migration of fine particle sizes into the conduits and hence minimize the tendency for pipe clogging. Clogging is of particular concern where flow gradients are low and the soils to be drained contain soft silts and loose fine sands.

For corrugated plastic pipes, we have adopted, in general, the manufacturer's specifications for the filter sock, while for corrugated metal pipes, we have adopted the typical specifications shown in Table 1 developed for non-woven geotextiles.

TABLE 1. Geotextile Properties

Non Woven		Woven	
Grab Tensile Strength	600 N min.(warp) 600 N min.(fill)	Wide Strip Tensile Strength	30kN/m(Warp) 30kN/m(fill)
Grab Tensile Elongation	50% max (warp) 50% max (fill)	Wide Tensile Elongation	35%max.(warp) 35%max.(fill)
Mullen Burst Strength	1110 kPa(min)	Mullen Burst Strength	4000 kPa(min)
Permeability	0.01 cm/sec. min.	Permeability	0.01 cm/sec.min.
E.O.S	0.08 to 0.15mm	E.O.S	0.5 mm max.
Thickness	2.6 mm min.		

All tests except E.O.S according to relevant CGSB and ASTM standards. E.O.S according to U.S Army Corps (CW^{C}-02215).

It should be pointed out that the Department's practice is to order geotechnical products, as far as practicable, through generic specifications thereby giving suppliers and manufacturers a fair chance at competitive tendering.

Non-woven geotextiles are also used to envelope the entire drain. In most instances, where perforated pipes are also utilized in these drains, the preference has been to utilize corrugated plastic pipe with a filter sock. The use of geotextiles to envelope the drains is popular in the following situations:

(a) where geotextile and geomembrane combinations are used in sub-surface drainage.

(b) where flow gradients along the drain are small and the material contains loose fine sands and soft silts or other readily erodible and transportable material.

Where the subsoils are stiff and seepage emanates from thin sand/silt lenses or fissures, the use of a geotextile envelope is waived, especially if the drainage gradient is about 5% and greater. In some cases, we have conceived the use of geotextiles where the drainage aggregate contains a higher percentage of fines than the specifications normally allow.

Over the years, we have periodically examined the flow from drains incorporating non-woven geotextiles and have found that these installations are functioning very well.

EROSION CONTROL

The use of geotextiles in erosion control was very popular from around 1980. At that time, the Geotechnical Section became involved in finding solutions to long-standing erosion problems associated with the inability for grass growth to be promoted in areas of medium velocity flow along road side ditches.

The early trials utilized non-woven geotextiles as an underlay to pitrun gravel commonly used in many areas to stop erosion of roadside ditches and to treat washouts downstream of culverts.

The use of non-woven geotextiles in such situations met with varying success since on many occasions, depending on the flow, and the gradient of channel, the gravel was displaced and the geotextile exposed to the elements.

In some circumstances, water found new channels causing undermining of the installations. Non-woven geotextiles along with pitrun gravel are still utilized in some areas of the Province, especially where this approach results in a cost effective design.

However, a much greater emphasis has been placed on the size of gravel to be used, as well as channel characteristics. Designs now incorporate ditch check structures at intervals of 10 to 20m to prevent loss of aggregate cover.

For a few years, the use of non-woven geotextiles in erosion control increased quite rapidly. This was consistent with the development by the Department of a flexible erosion control mat made with concrete nodules. The geotextile was utilized as an underlay for this mat in ditches where silty soils were predominant or where grass growth was difficult to promote using common practices of hydroseeding and strawbale installation.

For these installations, the geotextile was conceived to maintain the grass seeds in position to ensure their germination. Many of these installations worked well while others suffered failures caused by poor installation techniques, breaching of the installation through errant water flow, and siltation. A typical installation using the geotextile underlay is shown on the left half of Fig.2.

In situations where no grass growth could be conceived, geomembrane underlays were utilized below the concrete mat. To avoid puncturing of the geomembrane during installation, the geomembrane is overlain by a non-woven geotextile and sometimes sandwiched between geotextile layers, as shown on the right half of Fig.2.

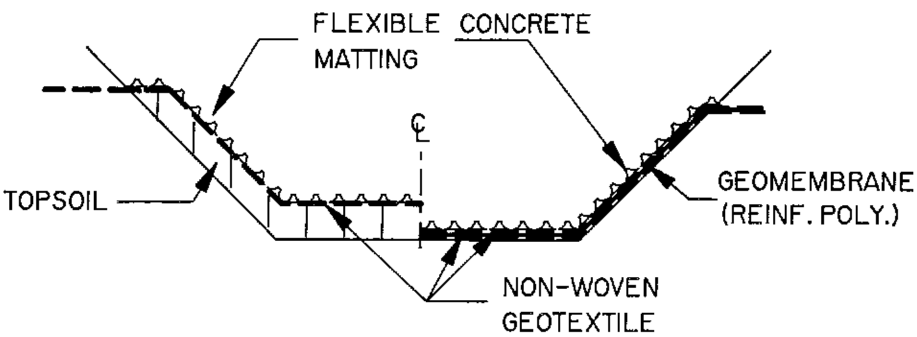

Fig.2. Use of Geotextiles and Geomembranes with Flexible Concrete Erosion Control Mat.

Strawbales, because of their availability and cost, are traditionally used along highway ditches as the first step in erosion mitigation to encourage grass growth and minimize siltation. Strawbales, however, suffered the criticism of being useless since many installations were found to be ineffective. Careful scrutiny of installations revealed that if grass cover did not occur within a season or two the installations would eventually degrade.

Undermining of the strawbales was the typical failure mechanism. Based on field trials, installation techniques were improved through embedment of the strawbales into the channel, placing bales far enough up the ditch slopes, and reducing spacings to about 10 to 15 metres.

An additional feature which developed was the utilization of non-woven and woven geotextiles as well as geomembranes underlying the strawbales or to act as a splash pad. In this design, the geotextile underlay was conceived to prevent erosion at the downstream end of the channel immediately adjacent to the strawbales.

The use of non-woven and woven geotextiles has become increasingly popular for these installations depending on the characteristics of the subsoils, and the challenge to combat the variety of problems related to erosion in the highway system.

To a limited extent, geotextiles have been tried in the stabilization of sandy soil slopes. Here, a non-woven geotextile was used to prevent topsoil placed on the slopes from being displaced during the germination period. Where trials using different materials were adopted, the geotextile treated area also had grass growth, though not as prolific as the other areas.

Another popular use of geotextiles is in the construction of silt fences. This application has been undertaken mainly to prevent problems of siltation at culvert inlet and outlets and of sensitive streams and rivers.

The Department has also been utilizing geocomposites for several years for the specific purpose of erosion control. The general goal of these products is to afford protection to the site until vegetation takes over, or indefinitely where vegetation growth is not to be expected.

Some of the products utilized for the various flow types are listed in Table 3. Field trials are being undertaken to evaluate the performance of these and other products with the intent of developing a more comprehensive list of materials.

One of the more popular use of geotextiles is its use in gabion structures. Woven, non-woven geotextiles, and geomembranes have been utilized. The normal design incorporates a non-woven geotextile as underlay, but depending on site conditions, the other materials are also utilized.

Specifically, the use of a geomembrane underlay may be conceived for use in an areas where possible leakage from the structure would result in undermining of the subsoils. We have utilized this approach in a landslide area where the terrain was particularly susceptible to instability from seepage.

For these installations, the materials used are shown in Tables 1 and 2.

In a similar manner, non-woven geotextiles are often utilized under riprap to protect bridge headslopes and culvert inlets and outlets from erosion. For these types of installations a thicker geotextile is often specified to offset the probability of impact damage.

TABLE 2. Geomembrane Properties

REINFORCED POLYETHELENE		PVC	
Tensile Strength	700 N min. (warp) 700 N min. (fill)	Tensile Strength	14 MPa min. (warp) 14 MPa min. (fill)
Tensile Elongation	60% max. (warp) 60% max. (fill)	Tensile Elongation	300% min. (warp) 300% min. (fill)
Tear Strength	120 N min. (warp) 120 N min. (fill)	Tear Strength	45N/mm min(warp) 45N/mm min(warp)
Mullen Burst Strength	3000 kPa min.	Thickness	0.75 ± .05mm
Thickness coating(top and bottom)	0.035 mm min.	Pinhole and Cracks/10 m^2	1 max
Mass	120 g/m^2 min.		
3 ply min.30 by 30 tapes/10 cm			

All tests according to the relevant CGSB and ASTM standards.

TABLE 3. Vegetation Promoting Erosion Control Mats Grades Between 5 and 10%

FLOW TYPE	MATERIAL	WEIGHT
Low	Excel Regular Erosion Control Blanket	0.53kg/m^2
	Standard Curlex Blanket	0.53kg/m^2
	Excelsior Erosion Control Blanket	0.46kg/m^2
Medium	Excel Super Duty Excelsior Blanket	0.87kg/m^2
	High Impact Excelsior Blanket	0.54kg/m^2
	High Velocity Curlex	0.86kg/m^2
Heavy	Enkamat 2010	0.24kg/m^2
	Permamat 200F	1.26/g/m^2
	P-300	0.43kg/m^2

DRAINAGE

Initially, all uses of geotextile where water could be removed were considered related to drainage. However, filtration and drainage are recognized as distinct functions.

In this context, the drainage function has been related to use of geotextiles, geocomposites-wick (prefabricated) drains, sheet drains and edge drains. Vertical wick drains have been used extensively and with much success, while lateral wicks were designed for one project but were not implemented.

The drainage concept has been used in relation to frost heave mitigation by placing a non-woven geotextile at the undercut level to act as a capillary break. This use is still questionable but is attractive when all other viable concepts prove difficult to execute or too costly.

Sheetdrains, consisting of a raised core structure, polyethylene or polypropylene as a core polymer, and non-woven polypropylene geotextile as the outer covering have been used quite recently as a subdrain to remove subsurface water from a sideslope, Fig.3. This type of drain was also used to remove water in a horizontal plane from wicks installed to aid ground consolidation.

In both instances, the high cost of procurement of granular material made the use of these materials viable. These trials were observed to be very effective as evidenced from movement of moisture through the drains.

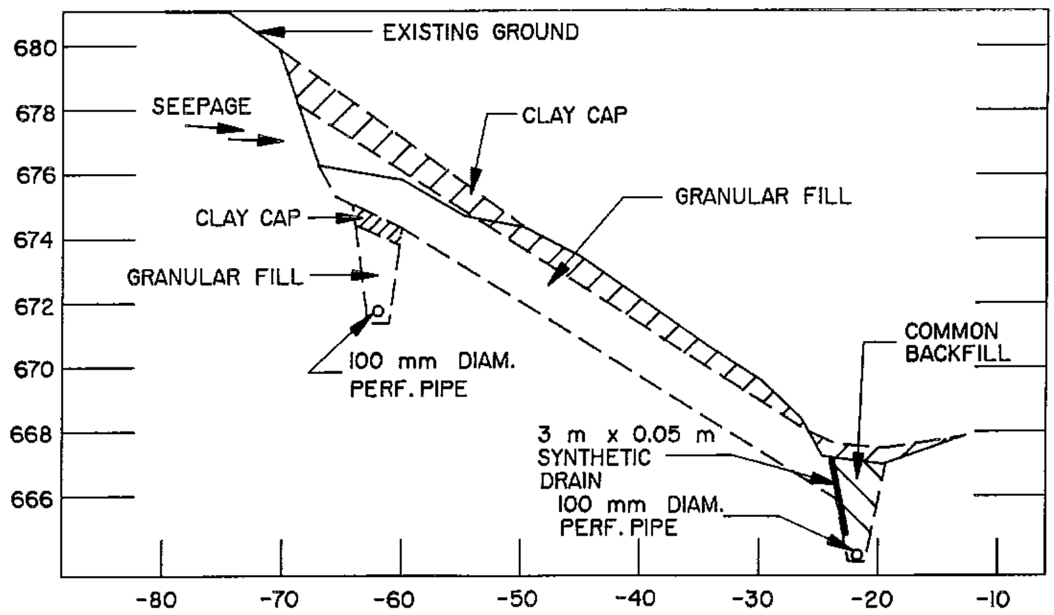

Fig. 3. Use of Sheet Drain in Subsurface Drainage.

REINFORCEMENT

The reinforcement function is also a very important use for geotextiles in Alberta since there are large areas in the Central and Northern part of the Province containing muskegs. While the traditional construction on muskegs has been to utilize a slow pace of construction and lightly loaded earthmoving machinery, the present day trend is to utilize geotextiles and larger earthmoving machinery (Diyaljee, et al,1986).

The use of Cat 631 scrapers or their equivalent has indeed complicated matters, since, while an embankment can be satisfactorily constructed on a muskeg by the stage construction approach, this construction cannot be readily accomplished if the hauling equipment fractures the muskeg.

Based on field observations and field trials, Alberta Transportation and Utilities has adopted the use of geotextiles for reinforcement of muskeg areas only under certain conditions (Diyaljee, 1988).

These conditions assume the adherence of specification requirements of light trafficking on the muskeg area. However, in certain critical projects the decision is made to utilize geotextiles depending on problems that could be associated with the occurrence of unforseen failures.

One of the outcomes of the field trials was that a woven geotextile should be used to reinforce muskeg areas. For muskeg deposits up to 4 metres in thickness overlying soft to firm ground, the woven geotextile in Table 1 is used. For projects where subsoil conditions are very poor, a design would be undertaken to assess the most suitable geotextile for use.

The use of the non-woven geotextile, which had been traditional since around 1977, is still being employed in situations where it is considered that the muskeg or soft ground was localized and shallow in extent.

There are numerous cases illustrating the use of woven geotextiles in muskegs. Figure 4 illustrates a typical design. The geotextile is placed perpendicular to the alignment and overlapped about 1 metre or stitched.

The use of a granular layer over the geotextile is not mandatory but is dictated by site drainability and trafficability considerations. Bowl shaped depressions, where drainage is generally poor, encourage the use of a granular pad to allow initial traffic to be sustained as well as the rapid expulsion of water during the very initial stages of loading .

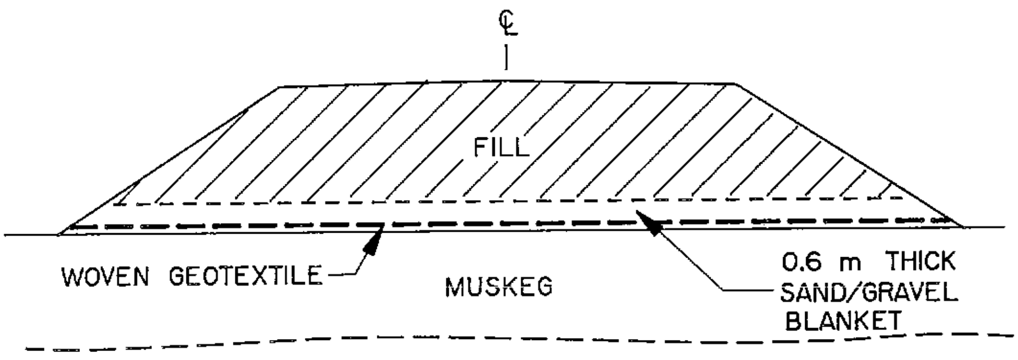

Fig. 4. Use of Woven Geotextile in Reinforcement of Muskegs.

While the use of geotextiles is somewhat popular for reinforcement of slopes, much use has not been made of this type of design. Nowadays, geogrids appear to be the preferable material for slope reinforcement.

Woven geotextiles, however, have been used as temporary reinforcement to a bridge headslope fill which was to be oversteepened by pier excavation close to the headslope. Using a vertical spacing of 1 metre a certain zone of the headslope was reinforced to provide an additional safety factor against slope instability.

In typical embankment reinforcement, the geotextile is placed horizontally as the embankment construction progresses. However, for embankments that have failed, geotextiles have been used parallel to the slope at or near the plane of failure. A design used to repair a headslope slide caused by the combination of wet fill material and pier excavation is shown in Fig.5.

In similar fashion, a geomembrane has been utilized in combination with a non-woven geotextile for a slide repair, where water infiltration as well as some reinforcement were considered to be critical to the stability of the slope, Fig.5 (inset).

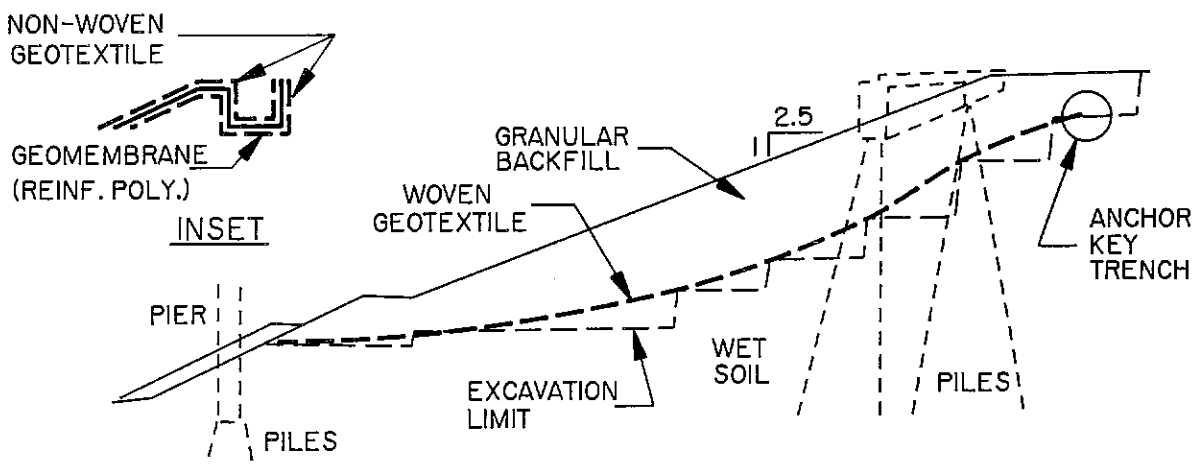

Fig. 5. Reinforcement of Failed Slope.

SEPARATION

Geotextile and geomembranes can be conceived to provide separation between dissimilar materials. Such separation is common to ensure, for example, integrity of one of the materials. A popular usage is the prevention of contamination of granular basecourse material from a subgrade that is soft or silty.

The traditional separation has been undertaken using non-woven geotextiles, in most cases. In the case where reinforcement as well as separation is conceived, a woven geotextile is used. These geotextiles would have characteristics shown in Tables 1 and 2.

Another use of geotextiles for separation has been at culvert installations in very soft ground or muskeg areas. Here, non-woven and woven geotextiles have been utilized depending on whether ground settlement would be excessive or not. For excessive settlement, woven geotextiles are preferred, although non-woven geotextiles have also been used.

The concept of using geotextiles at these locations arose from two factors; one was the need to prevent loss of granular bedding material in soft ground, and the other to provide for some form of uniformity of settlement. The first aspect is considered the most important for many jobs. In addition, the geotextile provides a better environment at the excavation level for workers and light equipment engaged in culvert installation.

MOISTURE BARRIER

As discussed under filtration, geomembranes are utilized solely or in combination with geotextiles. The objective in using the geomembranes is to prevent flow to an area.

This technique has been used quite frequently in subsurface drainage to remedy frost heave problems, Fig 1, right side.

The use of geomembranes resulted from conceptual thinking from observation of projects where French drains installed in high cut-slopes perpendicular to the slope did not function effectively in removal of infiltration. In some cases, the drains were breached on the down-hill side by seepage exiting down-slope of the drain location.

It was observed that this situation was most likely to occur where gradients along the drains were small and backslopes were high and steep. The use of a geomembrane was conceived as a cut-off on the down hill side of the drain to ensure that seepage would be contained within the drain. This resulted in the use of geotextile and geomembrane combinations for specific topographic conditions.

In cases where the gradient along the drain is large, then the use of a geomembrane may be omitted from the design. Of course, there are situations where geotextile and geomembrane combinations cannot be used owing to slumping of the excavation hindering installation of the membrane.

Recently, thick PVC liners have been utilized as an moisture barrier liner to a depth of 3m below two longitudinal edges of an airport runway, Fig.6. This design was adopted after the investigation for frost heave and swelling problems showed that moisture could not be effectively drained from the site. Since installation about 2 years ago no reports have been made about further deterioration of the pavement structure.

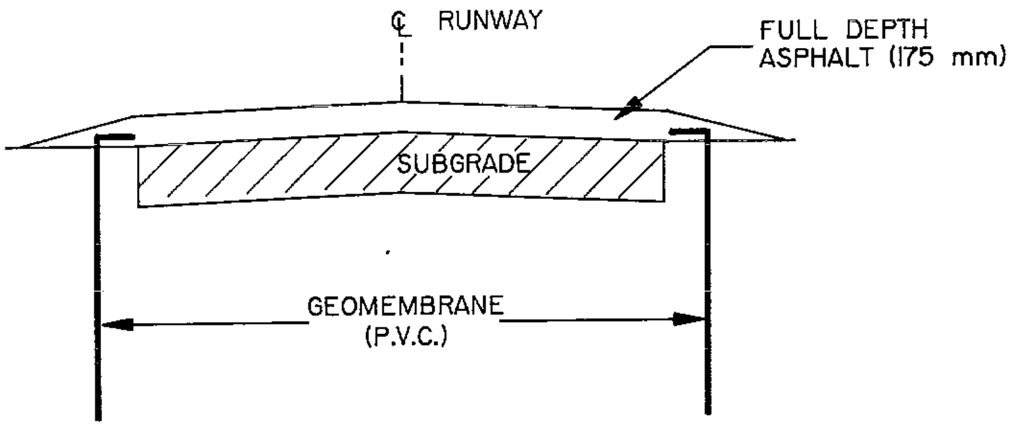

Fig. 6. Use of Geomembrane as Vertical Moisture Barrier.

Geomembranes have also been used for the treatment of frost heave areas through their installation horizontally in the roadbed. Such designs utilize the impermeable nature of the geomembrane to prevent the growth of ice lenses.

In one such trial, the material was placed at or near to the frost depth and proved to be effective in the mitigation of further frost heaving, Fig.7.

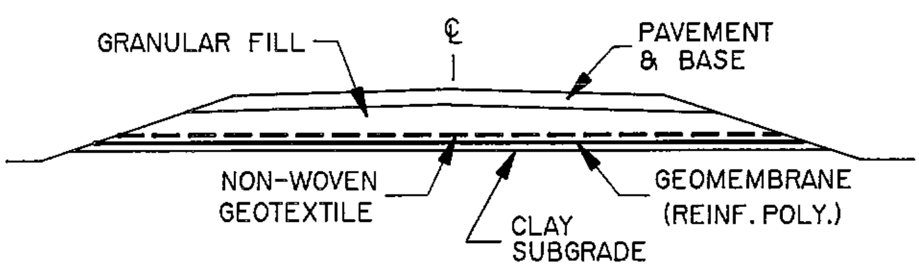

Fig. 7. Use of Geomembrane in Frost Heave Mitigation.

The use of geomembranes has been conceived at-grade railway crossings where rough riding conditions caused by bumps generally occurs at or close to the intersection of the railway crossing and roadway. Settlement and heave caused by frost action are frequent causes of this rough riding condition. The ballast at the intersection provides a sink for water from snow melt and rainfall to migrate downwards to the roadway subgrade .

The design shown in Fig.8 is one of the variations to prevent seepage from migrating into the subsoils and thereby minimizing frost heaving. Since some of these areas are relatively flat and drainage may not work perfectly, the geomembrane would at least prevent the subsoils for becoming saturated.

This design has been utilized quite recently and the benefits are not yet fully known.

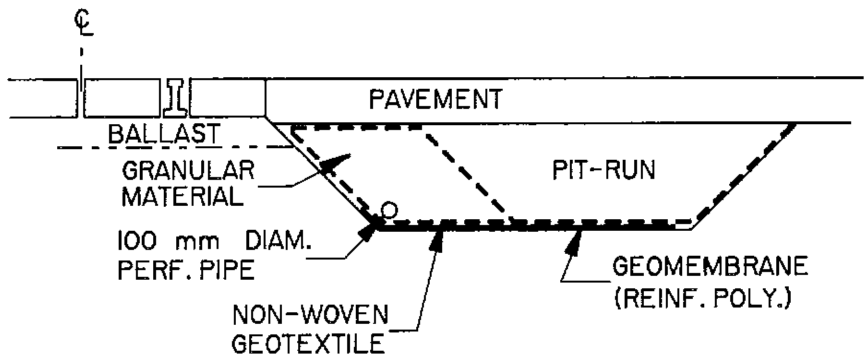

Fig. 8. Use of Geomembrane at Railroad Crossing.

Recently, it has been considered that sheet drains or edge drains could provide the same effect as the geotextile-geomembrane combined drain for subsurface drainage since one side would provide infiltration and the other act as an impermeable barrier. This type of drain could also be utilized to reduce the excavation required for traditional trench drain with or without a geotextile envelope.

MATERIAL USAGE

As mentioned previously, geotextiles have been utilized by Alberta Transportation and Utilities since around 1977. From that time to now, several thousand square metres of geotextiles and geomembranes have been utilized throughout the Province in different types of applications. Records of material usage have been kept in a dedicated fashion by the Geotechnical Section since 1985.

Figure 9 illustrates the use of the various types of geotextiles and geomembranes over the last 6 years. This figure summarizes the amounts used in construction and maintenance operations. The average cost for non-woven geotextile in this period was around \$1.02 per m^2, while the woven was around 90 cents per m^2.

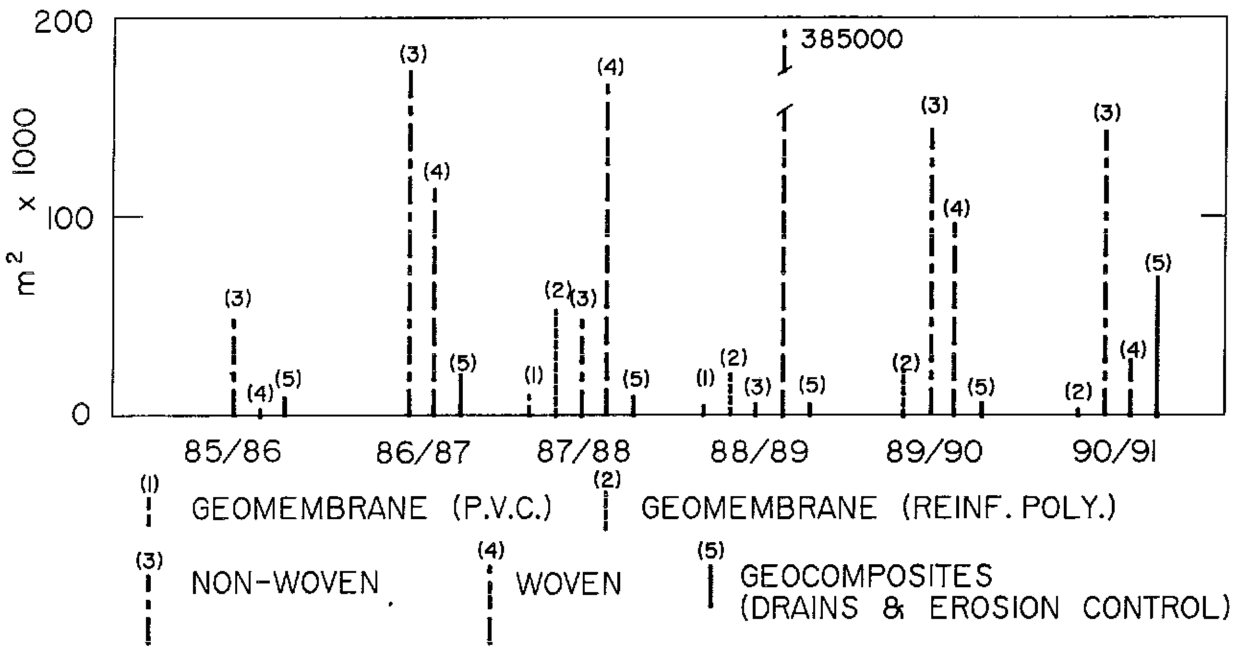

Fig. 9. Utilization of Geotextiles, Geomembranes, and Geocomposites 1985-1990

The trend of material usage in Fig.9 shows a generally decreasing use of woven geotextiles and a more or less constant use of non woven geotextiles. The use of geomembranes is also on the decline.

It is anticipated that with new infrastructure construction decreasing and maintenance of existing facilities become more important, the overall use of geotextiles will decrease even further.

On the other hand, it is anticipated that the use of geocomposites will be promoted as the concern about the environment becomes more concentrated. As shown in Fig.7, there is a steady increase in geocomposites for erosion control mitigative measures.

QUALITY CONTROL/QUALITY ASSURANCE

The Department purchases geotextiles and geomembranes and any other of these material types through competitive tendering using, as far as practicable, generic specifications. The condition for tendering includes the provision of mill certificates attesting to the quality of the rolls to be supplied. In addition, random testing is being undertaken to assess whether geotextiles and geomembranes are meeting the specifications requested.

CONCLUSIONS

Alberta Transportation and Utilities has been utilizing geotextiles and geomembranes on highways construction for about 13 years now. The use of these materials has now been common in many situations related to filtration, drainage, reinforcement, separation, and moisture migration in highway construction.

Over the last 6 years several uses have been made, both in the traditional and non-traditional sense, to solve a variety of problems. The use of geotextiles and geomembranes is regulated in the Department and the majority of applications are through approval from the Geotechnical Section.

It is expected that use of wovens will decline, while the use of non-wovens will increase as environmental concerns related to highway construction takes the lead.

In the future, we would anticipate more creative and innovative uses for geotextiles and geomembranes in maintenance oriented operations.

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