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**INTRODUCTION**

Comment presented here will deal with three topics:

1. Geosynthetics as used in highway edge drainage;
2. Geotextiles for railway applications;
3. Geosynthetics used in embankment construction on very soft soil such as deposits involving peat.

**GEOSYNTHETICS USED IN PAVEMENT DRAINAGE**

The importance of good highway drainage has been recognised for many centuries. Examples include the Roman roads with well conceived and constructed drainage systems that remain today (1997), and the works of the early nineteenth century engineers. Despite this history, recent aggregate grading emphasis has been on aggregate density and stability rather than permeability. Some exceptions are the work of Cedergren et al. (1973), and others but, unfortunately, good drainage design and construction are not as simple as generally suggested, particularly in a cold climate. While good drainage design includes provision for surface drainage, ground water lowering and internal drainage, this panel presentation focuses only on one aspect of internal drainage, namely edge drainage, as it relates to cold climate conditions experienced by Ontario highways. Internal drainage is the collection and discharge of water that may enter the pavement structure through the wearing course (e.g., surface cracks), granular shoulders or from the subgrade, and is facilitated by subdrains, French drains, geocomposite drains and/or open-graded drainage layers (OGDL).

The freezing index in Ontario ranges from 500 °C-days upwards. An example of measured Benkelman beam highway rebounds that resulted from these severe weather conditions is shown in Figure 1. To balance pavement survival from severe weather with acceptable capital costs, typical Ontario highway new pavement design to a freeway standard is summarized in Figure 2. Subgrades have a minimum 3% slope and are covered with a minimum thickness of 100 mm of densely graded granular aggregate (Granular 'A' similar to ASTM D-2940). OGDLs have been provided directly below the pavement course for many years on freeway standard highways. The OGDL consists of crushed aggregate graded from 26 mm down to 8 mm (i.e., 26/8 mm). These were initially daylighted to the ditch, but this has proved to be unsatisfactory (Hajek, et al., 1992). Ditch inverts are 500 mm or more below the lowest subgrade elevation. The pavement wearing surface is sloped, or centre line crowned, ending with a 2% or more falling slope at the pavement edge. Today (1997) shoulders are 3 m wide with a 0.6 m or more portion partially paved and integral with the pavement. The unpaved portion has a 6% or more slope and is constructed of Granular 'A' to the subgrade elevation. Initially most shoulders were unpaved, then retrofitted with 0.6 m of partial paving.

In most cases the daylighted OGDL was retrofitted with a geosynthetic edge drain (GED). Figure 3 shows a typical

installation. As seen the GED was placed adjacent to the concrete pavement edge in a trench cut with a vermeer cutter and boot (cut trench and guide).

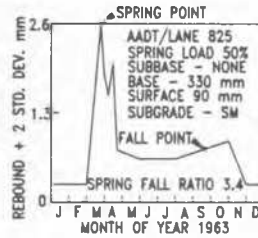


Figure 1. Pavement Benkelman rebounds (Raymond et al.,1996).

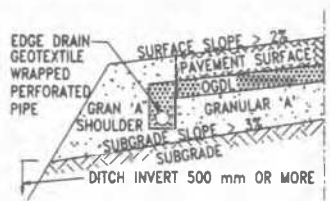


Figure 2. Ontario highway layer design with out-of-date edge drain (Raymond et al., 1996).

Observations made during the winter showed frost heave between the loaded pavement and its unloaded shoulder. In some cases the geocomposite rubbed against the pavement edge exposing the cusps of the geocomposite. The heave observations are analogous to a loaded and unloaded laboratory test sample. The heave causes the OGDL drainage path to be severed as illustrated in Figure 4.

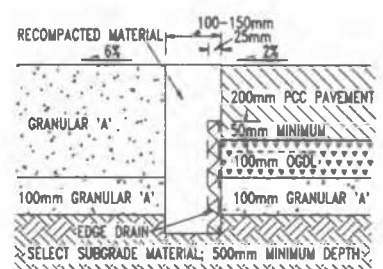


Figure 3. Out-of-date edge drain layout (Raymond et al., 1996).

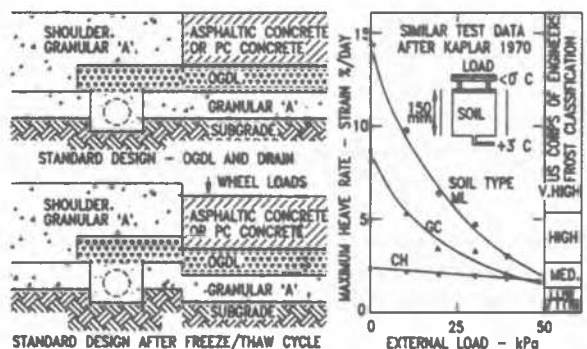


Figure 4. Concept of observed behaviour (Raymond et al., 1996).

While it was evident that the trench for the retrofit drains must be placed as close to the pavement edge as possible it is now apparent that the GED should not be placed against the face of the pavement. It was also evident from the observations that the GED performance is contrary to the generally accepted geotextile filter concepts.

These concepts require that the permeability of the soil, or in this case the OGDL, be at least an order of magnitude less than the permeability of the geotextile, e.g., Giroud (1982). A new concept was needed if a GED is to be used.

The OGDL needs to discharge into a trench filled with a high permeability backfill with the GED on the shoulder side of the trench. The surface area of the GED geotextile receiving water would then be considerably larger than its former area contacting the OGDL. Under proper construction, undesirable voids would not develop between the OGDL and the backfill. Using a surrounding sand, rather than gravel, and care during installation, a low mass per unit area geotextile, as presently used by MTO, should be sufficient. Figure 5 shows the newly adopted layout for a retrofit drain with the GED on the shoulder side. The backfill consists of an extra clean sand, preferable manufactured and graded to that of concrete sand (ASTM C-33) with the additional requirement of 0-2% by mass at the 75 µm sieve size. The trench base should have a bedding layer where practical. This is to protect the conduit from infiltration of subgrade fines.

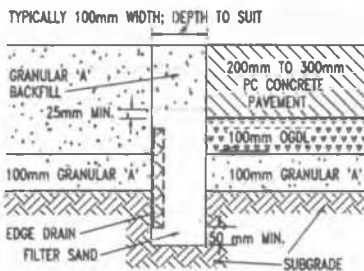


Figure 5. New retrofit geocomposite details (Raymond et al., 1996).

An edge drain located next to the pavement edge is still capable of differential frost heave in relation to the pavement. To prevent differential frost heave it is now Ontario practice to locate new highway construction edge drains below the pavement, or partially paved shoulder where the paved shoulder portion is made integral with the pavement. Figure 6 shows typical details of a new construction edge drain installation.

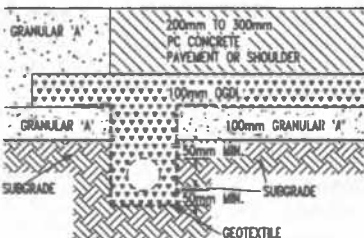


Figure 6. New edge drain details (Raymond et al., 1996).

In addition, for both retrofit and new construction, the outlet inverts must be dropped to the invert elevation of the trench in much the same way as illustrated in Figure 7 and 8. Further details have been presented by Raymond et al. (1996).

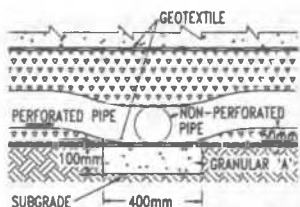


Figure 7. Longitudinal section through new outlet (Raymond et al., (1996).

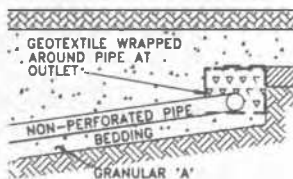


Figure 8. Lateral section through new outlet (Raymond et al., 1996).

## GEOTEXTILES FOR RAILWAY APPLICATIONS

In the 1970's geotextiles were introduced into North American railway tracks to correct some of their track support problems. Examination of the sites where geotextiles were installed showed that the track had inadequate internal track drainage, whether because of topography or because of created drainage problems. In

North America such poor drainage areas are aggravated by the freezing weather, the use of freight cars with wheel loads up to 180 kN, and annual freight that can exceed 530 GN per track.

Studies by the writer and co-workers have shown that correct installation procedures are essential. If geosynthetics are installed correctly the main functions of track rehabilitation geotextiles for North American conditions are as given below:-

(a) **Drainage**:- the ability to drain water away from the track roadbed, on a long term basis, both laterally and by gravity, along the plane of the geotextile without build up of excessive hydrostatic pressures.

(b) **Filtration**:- the ability to filter or hold back soil particles while allowing the passage of water.

(c) **Abrasion resistance**:- the ability to withstand the abrasive forces of moving aggregate caused by the tamping/compacting process during cyclic maintenance, tamping during initial compaction and by the passage of trains on a frequent basis.

(d) **Separation**:- the ability to separate two types of soils of different particle sizes and grading that would readily mix under the influence of repeated loading and water.

(e) **Elongation**:- the ability to elongate around protruding large gravel-sized particles while resisting rupture, puncture or cutting.

(f) **Reinforcement during thaw**:- since a thaw occurs mainly from the top frozen surface the geotextile must permit water to drain upwards while preventing the penetration of the ballast into the softened thawing underlying soil.

The importance of proper geotextile installation and specification can be briefly illustrated by means of the following comments. In general a track is not removed during ballast replacement. Rather the ballast is undercut with either a chain saw type blade that extends under the track from one side only, or a chainlike belt feeding down under one side of the track and up the other side. Figure 9 shows the undercut surface upon which the geotextile is to be placed. In all cases, where the track is not removed, the surface produced has ballast size particles protruding from the surface. These protruding ballast particles must be covered by the geotextile without causing the geotextile to be punctured. Geotextile elongation has been found essential. This dictates the use of a non-woven material without reinforcement woven fibres. Incidentally, about 100 mm below this surface shown in Figure 9 is a clean filter sand used to prevent subgrade fouling of the ballast. No subgrade fouling existed at this site.



Figure 9. Stone particles left after undercutting will eventually pierce a lightweight geotextile.

Figure 10 shows how the geotextile is installation below the tracks. At all times the geotextile should be handled and installed with care.

Figure 11 shows the ballast bag protection used to prevent tamper tine damage to the geotextile during ballast compaction. Also

shown is the undercutter trench that should be maintained, otherwise the fouled shoulder ballast must be removed. If the trench method is used, the geotextile should be turned down to line the trench and to facilitated drainage. Once the trench is lined with the geotextile edge it should be filled with clean ballast and outlet pipes used to ensure trench drainage.



Figure 10. Geotextile installation below tracks. At all times, geotextile should be handled and installed with care.



Figure 11. The installation crew has drapped geotextile into cut trench to allow the geotextile to facilitate drainage.

Figure 12 shows the ballast car filling the undercutter trench. This is being filled first to give some tension to the geotextile in case thaw softening occurs during spring break up.

Raymond (1984) outlined a specification for use by Canadian Railways. Geotextiles meeting this specification have been installed at the rate of more than 50 installations per year over the last sixteen years. All these installations continue to give satisfactory performance. Raymond (1994) records that the durabilities of the geotextiles have been excellent. In addition the installations have turned out to be very cost effective. The main details of the Raymond (1984) specification is as follows:

**Type:-** Needlepunched non-woven with 80 penetrations per  $\text{cm}^2$  ( $80 \text{ p/cm}^2$ ) or greater.

**Fibre Size:-** 0.7 tex or less.

**Fibre strength:** 40 micro neutons per tex ( $\mu\text{N/tex}$ ) or greater.

**Fibre polymer:** Polyester.

**Yarn length:** 100 mm or greater.

**Filtration Opening Size:-** 75 micrometres ( $\mu\text{m}$ ) or less.

**In-plane coefficient of permeability:-** 50 micrometres per sec ( $\mu\text{m/s}$ ) or greater.

**Elongation:-** Sixty percent or more to ASTM D-4632.

**Seams:-** No longitudinal seams permitted.

**Colour:-** Must not cause "Snow Blindness" during installation.

**Packaging:-** Must be weatherproofed and clearly identified at both ends stating manufacturer, width, length, type of geotextile, date of manufacture.

**Wrapping:-** 8 mil black polyethylene or similar.

**Abrasion Resistance:-** 1050  $\text{g/m}^2$  geotextile must withstand 200 kPa on 102 mm burst sample after 5000 revolutions of H-18 stones each loaded with 1000 grams of rotary platform double head abrador (ASTM D-3884).

**Width and length without seaming:-** To be specified by client.

**Fibre bonding by resin treatment or similar:-** not less than 5% nor more than 20% by weight of low modulus acrylic resin or other suitable non water soluble resin that leaves the geotextile pliable.

**Mass:-** 1050  $\text{g/m}^2$  or greater for track rehabilitation without the use of capping sand.



Figure 12. Trench should be filled first to result in tensioning. Ballast filled side trenches promote drainage as long as outlet pipes are installed.

## EMBANKMENT CONSTRUCTION ON VERY SOFT SOIL USING GEOSYNTHETICS

Problems involving the construction of earth fills and embankments over very soft soil such as peat or soft clay are ideal candidates for ground reinforcement and berm loading (Raymond, 1969). The reinforcement was formally done by logs but today is either supplemented with geosynthetics or done solely with geosynthetics. Figure 13 shows the typical sequence of construction described by Raymond (1969). Figure 14 is a photograph taken from an in-place berm with tree logging reinforcement ready for placement within the central load bearing area of an embankment being constructed to support a highway pavement.

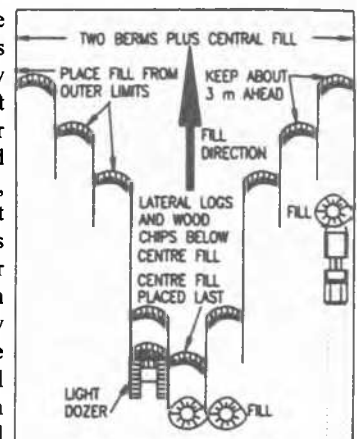


Figure 13. Sequence of construction on soft soil (Raymond, 1969).

Figure 15 is a photograph taken during construction of a central fill being compacted. An immensely important point is the fact that the "grade stacks" are being used as "thickness stakes." This is because the settlements occurring during construction are large. If the "grade stakes" are used during fill placement, excessive



Figure 14. Note in-place berm in foreground with tree logging reinforcement ready for placement within the central load bearing area.



Figure 15. Construction to thickness. Note grade stakes settle with construction.



Figure 16. Large differential settlements occur at small changes in loading.

settlement occurs, often resulting in ground failure.

Figure 16 shows an instrument box housing on the left of the photograph. Originally the top of the box was level. The sloped condition illustrates the large differential settlements that occur between the area of high loading (central fill) and low loading (berm fills).

Figure 17 shows some of the settlements recorded during construction. Note the heave that occurred during berm placement. This will reduce central fill settlement that is large. Where construction is to grade rather than thickness the central settlement results in an unacceptable large amount of central fill loading.

Figure 18 shows a geosynthetic combined with tree logs as reinforcement. In the background rutting is clearly evident. This

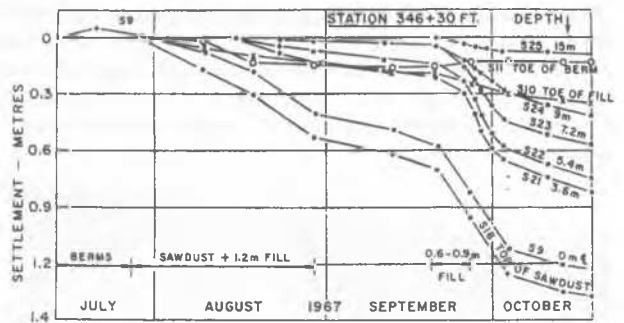


Figure 17. Embankment construction settlements. Note heave after berm placement (Raymond, 1969).



Figure 18. On haul roads rutting occurs unless granular thickness reduces subgrade stress to four times clay surface shearing strength ( $4c_u$ , i.e.,  $0.67 \times CBR$ ).

rutting is occurring during construction and clearly illustrates the problems that will occur when fill depths are insufficient. Based on data by Steward et al. (1977) the depth of a fill should be deep enough to reduce the vertical stress at subgrade level to  $4c_u$ .

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