Landfill Cover Soil Drainage

Suitability of Geotextiles with Unidirectional Drainage Elements

Technical Note

Introduction

Landfill cover soil layers typically include an impermeable barrier at the base (usually a geomembrane or geosynthetic clay liner (GCL), see Figure 1). This prevents rainfall permeating into the waste below which may result in excessive levels of leachate discharging into the environment. Landfill regulations require a drainage layer above the impermeable barrier to rapidly drain rainwater out of the cover soil. This is necessary to prevent saturation of the cover that may cause instability and saturation of the soil/barrier interface that would increase infiltration. Traditionally this drainage layer has consisted of a permeable gravel layer or, in more recent decades, a drainage geocomposite with equivalent performance. Both solutions provide drainage in both the down-slope and cross-slope direction. More recently, geotextiles with attached unidirectional drainage elements (such as a 100mm wide drainage strips or perforated 10-20mm diameter mini-pipes) have been proposed. These systems provide suitable drainage in the down-slope direction and very low cross-slope drainage. This technical note considers the implications that this has for the cover soil system with comparison to drainage geocomposites with an open, bi-directional void space.

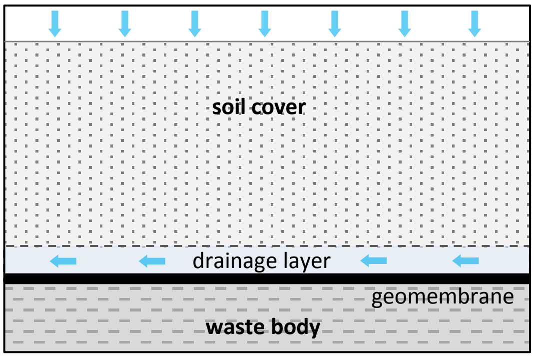

Figure 1: Typical Landfill Capping

Water Conditions in Geotextiles with Drainage Elements & Cover Soil Saturation

A geotextile with unidirectional drainage elements typically uses a 500g/m^2 or more geotextile with an in-plane flow capacity in the region of 0.0001 l/m·s (in a typical cross-slope capping application: hydraulic gradient i = 0.01; pressure of 20kPa). Flow rates this low mean that it would take a drop of water approximately 10 hours or more to travel one metre through the textile. The geotextile alone does not provide enough flow capacity so unidirectional drainage elements (such as 100mm wide drainage strips or 10-20mm diameter mini-pipes) are attached at around 0.5m to 1m centres to provide flow capacity in the down-slope direction. The geotextile is intended to transport the water in the cross-slope direction, into the drainage elements.

In order for water to flow, a hydraulic gradient must exist. This can be provided by either gravity or pressure. When considering water on a zero slope the pressure at one end must be greater than at the other in order for water to flow. When considering a landfill capping situation, flow in the down-slope direction has a hydraulic gradient provided by gravity, so no excess pressure is required. In order for water to move in the cross-slope direction a pressure differential must exist.

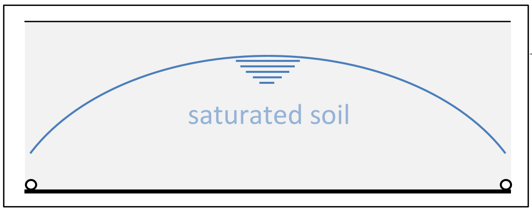

Figure 2: Geotextile with mini-pipes

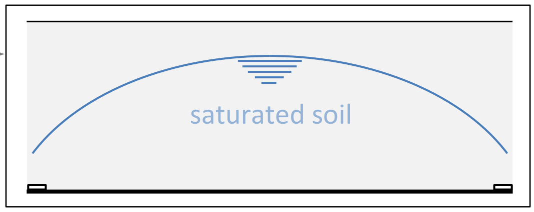

Figure 3: Geotextile with drainage strips

Water pressure is considered in terms of 'head' which is the height that a column of water would rise to at a given point (see Figures 2 & 3). Another way of thinking is to consider it as the height of saturated soil above the base of a drainage medium required to generate adequate flows. Generally speaking, in landfill design rainfall events, with typical covers soil, the head required to generate cross-slope flows in a geotextile is between 1mm and 100mm. So the soil cover will be saturated anywhere between 1mm and 100mm above the geotextile.

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In addition to this, the down-slope unidirectional drainage elements are located above the geotextile. So when laid on the impermeable barrier below, this leads to the requirement for the geotextile to be fully saturated, plus a head of saturated soil, to allow the water to move up into the drainage element.

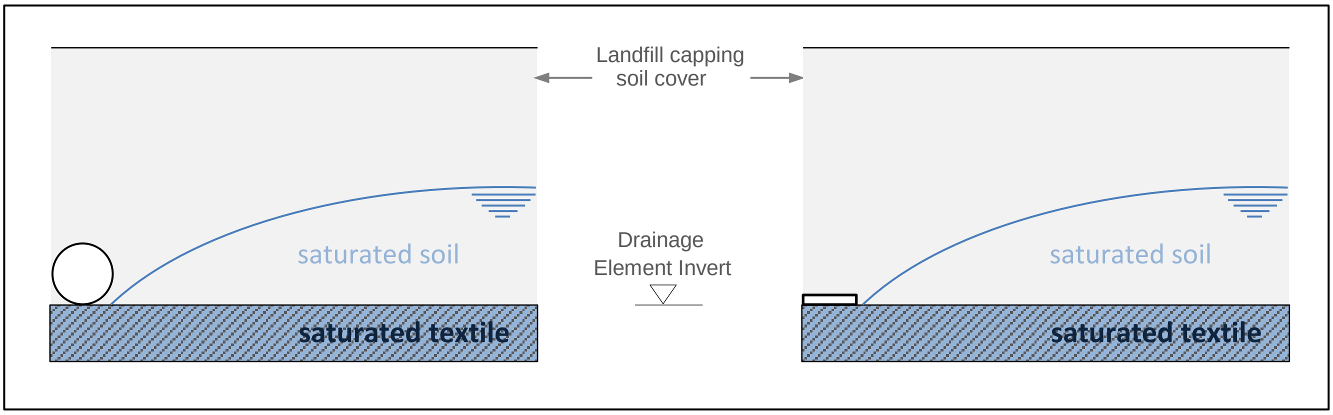

Figure 4: Water conditions of geotextiles with drainage elements: Mini-pipe (left) and drainage strip (right)

The overall result is that, in order for water to flow from the geotextile to the drainage elements, the geotextile and soil immediately above it must be saturated (see Figure 4). When a head of saturated soil drops below the invert level of the pipe/strip there is no longer any cross flow. Therefore, the textile and the soil above it will remain saturated and this will affect slope stability.

Water Conditions in Drainage Geocomposites with a Bi-Directional Void Space

Drainage geocomposites with an open, bi-directional void space (henceforth referred to as just 'drainage geocomposites'), provide high flow capacity in both down-slope and cross-slope directions (like gravel drainage layers). For comparison, a 450g/m^2 geotextile and a drainage geocomposite of similar thickness were tested by an independent UKAS accredited laboratory and found the geocomposite flow capacity to be 205 times higher than that of the geotextile.

Product Type	**Thickness**	**Flow** (i = 0.01, P = 20kPa)
450gsm Geotextile	(3.65m)	0.00039 l/m/s
Drainage Geocomposite	(4mm)	0.08 l/m/s

This is because drainage geocomposites consist of a rigid geospacer (e.g. an HDPE cuspated sheet, referred to as the 'core') which provides an open void for water flow in all directions across the entire area of the composite, rather than providing discrete unidirectional drainage elements in one direction. A geotextile is bonded to the core on one or both sides and the geotextile typically has zero breakthrough head to ensure that all water in the soil above travels directly into the core and so prevents saturation at any point. This is crucial for the landfill cover soil stability and infiltration control.

Veneer Slope Stability in Saturated Conditions

Internal Stability of the Cover Soil

"It is well understood that rainfall infiltration decreases the unsaturated shear strength of a soil slope due to the reduction in matric suction as the wetting front moves through it" (Mahmood, 2015).

The loss of shear strength of a soil when it becomes saturated is significant and is generally why landslides occur with heavy rainfall. This is due to a loss in matric suction. Essentially, when a soil is unsaturated, there is surface tension generated, between the air and the water, within the voids between soil particles. This provides a cohesive force which

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increases the shear strength of the soil. This effect is most pronounced in fine grained soils and decreases as the degree of saturation of a soil increases. Once the degree of saturation is 100% (fully saturated) the surface tension is zero, the matric suction force is zero, and the shear strength of a soil is greatly reduced (see Figure 5).

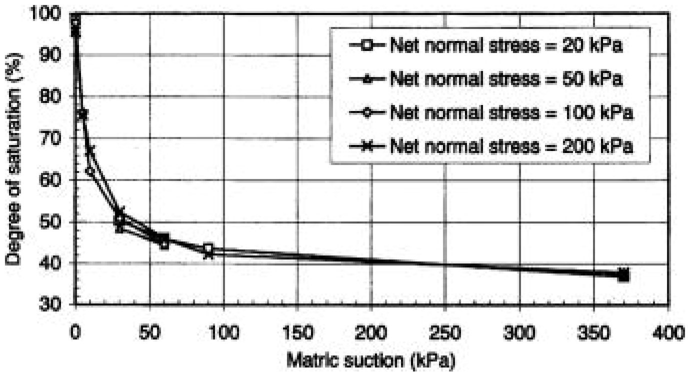

Figure 5: Degree of Saturation vs. Matric Suction

When drainage is provided by geotextiles with unidirectional drainage elements, the geotextile and soil immediately above it are saturated. This means that a layer of low shear strength soil will be formed immediately above the geotextile which can lead to sliding of the cover soil and failure of the capping system.

In contrast, drainage geocomposites ensure that all water in the soil above travels directly into the core and so prevents saturation at any point, maintaining the shear strength of the cover soil and the stability of the capping system.

Stability of Veneer Slope Interfaces

"*... the factor of safety of a layered system [landfill capping layer] with water flow [saturated soil] can be as low as one half of the factor of safety without water flow.*" (Giroud, 1995)

The purpose of a drainage system at the base of a landfill capping layer is to ensure that water is drained from the cover soil as quickly as possible to ensure that the cover soil remains unsaturated and stable. Without a drainage layer, the entirety of the cover soil may become fully saturated. Even if the cover soil itself is strong enough to maintain its stability, this results in a significant decrease in veneer slope stability at the interfaces between the soils and geosynthetics of the layer system that makes up the boundary between the landfill waste and the cover soil (see Figure 6). There are three main factors that destabilise these interfaces; the increase in the weight of the soil as the soil becomes saturated; the water pressure generated by the thickness of the saturated soil; and the wetting of the interface.

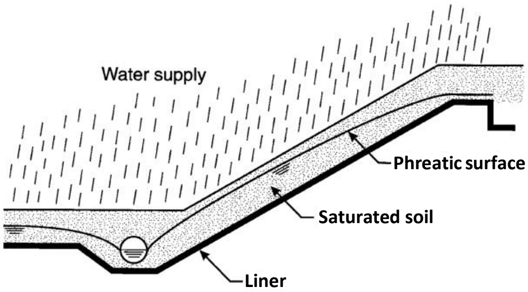

Figure 6: Saturation in Capping Layer

With geotextiles with unidirectional drainage elements, the geotextile and soil immediately above it are saturated. This means that the soil is heavier, and above the impermeable liner there is a water pressure added to the interface and the interface is permanently wetted. This can combine to significantly reduce the interface(s) factor of safety against slope failure. Drainage geocomposites ensure that all water in the soil above travels directly into the core and so prevents saturation to ensure slope stability.

Additional Considerations

Blocked/Damaged Unidirectional Drainage Elements

If a blockage occurs at any point or there is damage caused during installation, drainage geocomposites with high cross-slope flow capacity will divert the water flow around the affected area. If unidirectional drainage elements within a geotextile becomes damaged or blocked, this will require the water to flow twice as far to reach the next drainage element, resulting in a four-fold (or higher) increase in the depth of saturated soil above the geotextile. This will exacerbate instability as outlined above and can lead to local failures.

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Leakage

Geomembranes, GCLs and clay layers are not 100% impermeable. Engineers expect a limited number of leaks to form in the liners and account for this in their designs. There may be holes formed during construction, wrinkles in liners, limited flow through the joints of geosynthetics, etc. With a geocomposite with unidirectional drainage elements these holes will be covered with a saturated geotextile allowing water into the holes unimpeded. Drainage geocomposites ensure wetting of the lining system is kept to a minimum and so reducing the amount of water entering a hole and reducing leakage rates.

Creep

All materials creep - permanent deformation under loading. Polymers of all kinds are known to creep to varying degrees over their lifetime. Geocomposites are tested using the Stepped Isothermal Method (SIM) to assess the amount of creep that can be expected over a 100 year period and so can be specified with the knowledge of adequate long term performance. Geotextiles with discrete unidirectional drainage elements may significantly reduce their flow capacity in the cross-slope direction over time which may lead to greater hydraulic gradients required to cope with water flows, leading to a greater depth of soil saturation and increased instability.

Conclusion

Geotextiles with unidirectional drainage elements are not recommended for use as drainage layers in landfill capping systems as they may lead to saturation and subsequent instability of the capping system – the very thing that a drainage layer is required to prevent. Instead a drainage geocomposite with an open, bi-directional void space should be used.

The water conditions in geotextiles with unidirectional drainage elements are such that, in order for water to flow from the geotextile to the drainage elements, the geotextile and soil immediately above it must be saturated. Saturation in the cover soil, even if only over a small depth, can lead to sliding of the cover soil and failure of the capping system. In addition, this means that the soil is heavier; there is water pressure above the impermeable liner; and a permanent wetting of the interface(s) between the soils and the geosynthetics of the landfill capping system. This can combine to significantly reduce the interface(s) factor of safety against slope failure.

In contrast, drainage geocomposites with an open, bi-directional void space ensure that all water in the soil above travels directly into the core and so prevents saturation at any point, maintaining the shear strength of the cover soil, preventing an increase in weight of the cover soil, ensuring there is no water pressure and minimising wetting of the interfaces of the landfill capping system. Thus maintaining the stability of the capping system.

References

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Koerner, R. M. (2012) *Designing with geosynthetics*. 6th ed. Xlibris Corp.

Mahmood, K., Kim, J., Ashraf, M. and Ziaurrehman (2015). The effect of soil type on matric suction and stability of unsaturated slope under uniform rainfall. *KSCE Journal of Civil Engineering*, 20(4), pp.1294-1299.

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