A case study of the use of geosynthetics in the capping of a hazardous landfill

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Abstract

One of the main purposes of capping a landfill is to limit the quantity of precipitation that infiltrates the waste and in so doing reduce leachate production. For this reason, a landfill capping system is made up of a series of elements to reduce infiltration and improve drainage. The landfill may also be reshaped so that it promotes free draining with suitable engineering of storm water control measures to ensure efficient drainage and to prevent erosion and damaging of the cap. This paper's focus is on the use of geosynthetics for drainage and erosion control in a landfill capping system. A short literature review on the subject is presented followed by a case study of a capping system that is implemented on a landfill site in Gauteng. Solutions developed on site to simplify the construction of capping works is also discussed.

Keywords: *Landfill capping system, Geosynthetics, Drainage, Erosion Control*

1 Introduction

The objective of landfill closure and rehabilitation is to ensure that there are no long-term adverse effects on the surrounding environment as a result of the landfill, and to ensure that the site is left in an environmentally acceptable condition. To meet these objectives, the design must provide a final landform that is free draining with suitable engineering of drainage, and storm water control measures, to ensure the integrity of the cap is maintained at all times.

Through the initial literature review, the paper clarifies the importance of adequate geocomposite drain design for use in a landfill capping system as well as cites the different types of erosion control measures. Due to the large range of products, the author has focused on the erosion control measure implemented in the case study which is the erosion control blanket.

2 Literature review

Richardson and Zhao (2003) said that any final cover will at some point in its life approach a state of saturation due to weather conditions and explain further that "If the transmissivity of the underlying lateral drainage system is inadequate, then the infiltrating water will begin to flow parallel to the slope and the seepage forces will reduce the stability." Richardson and Zhao (2003). Considering Darcy's law under a unit gradient, the design flow rate through the geocomposite drain can be calculated since the rate of infiltration is equal to the permeability of the material layer below which it is placed.

However, once the design flow has been determined a suitable geocomposite drainage system can be specified. The product specific flow rate however needs to be reduced due to conditions that will occur during installation and over the duration of its life. Koerner (2005) lists these site specific reduction factors which are a result of intrusion of the geotextile into the drainage core; creep deformation of the drainage core itself and chemical and biological clogging of the geotextile or within the drainage core. Geocomposite drainage layers are designed to drain into collection systems where the water is drawn out of the landfill capping system. In some cases it may be in the form of an outlet pipe that penetrates the capping layers and exits above surface into a surface water drainage system.

The exposed surfaces of these surface water drains can be lined with various materials to increase resistance to flow and to manage erosion. Through improved design and installation guidelines, erosion control materials are becoming progressively more effective. Theisen (1992) provides a rational outline for categorising the infinite selection of erosion control materials. The categories are:

- Temporary biodegradable (natural materials)
- Geosynthetic related (polymeric materials)
- Hard armor systems (concrete, stone, etc.)

Koernor, R and Koernor, G (2018) describe erosion control blankets as being "lightweight biaxially oriented nets manufactured from polypropylene or polyethylene… the fibers are held to the net by glue, lock stitching, or other threading methods". This makes geojute a special type of erosion control blankets because it is made entirely of jute which is a bulky natural yarn and woven into a thick mesh. Geojute facilitates establishment of vegetation on steep slopes due its ability to achieve intimate contact to the soil it is protecting. Furthermore, it helps provide reinforcement to the root system by becoming entangled with the vegetation growth.

According to Theisen, M. S. (1992) the most critical parameter in an engineering design is flow resistance before, during and long after vegetative establishment. Therefore, it is crucial when designers specify an erosion protection material for grassed slopes and waterways, that the longevity of the material is considered in light of the initial but also the long-term flow resistance required.

3 Case study

3.1 Background

The landfill site, which is situated in Gauteng, is classified as a H:H facility according to the Minimum Requirements for Waste Disposal by Landfill 2nd edition (1998). The staged closure capping design for Cells 1 to 5 was approved by Department of Water and Sanitation in November 2013. The disposal of waste into the cells continued until the end of 2015 when the cells were filled to final height.

3.2 Final shaping

The final shape of the landfill was designed to encourage surface water runoff and thereby ensure that the potential for infiltration of rain water into the waste body is limited. After the site is capped, all surface water draining from the site will be uncontaminated by the landfill site and can drain freely to the environment.

Since the landfill has been filled approximately 40m above ground level, there is a need for an extensive storm water management system. The plateau of the landfill has a ridge along its length, with gentle falls of 1 V in 20 H towards the crest berms and the side slopes of the landfill were shaped to a 1 V in 3 H fall. A triangular drain at the toe of the crest berm slopes towards a downchute from which the surface water is diverted and discharged to the environment. A berm and trapezoidal drain configuration is placed on the side slopes every 10 m in vertical height to limit erosion. A slope section is defined as the sloped area enclosed on either side by downchutes which consist of gabion boxes and reno mattresses. Half a slope area would drain to the downchute on each side – this is done by creating the high points of the slope drains in the middle of the slope section. These trapezoidal slope drains fall at a gradient of about 1 V in 150 H towards the downchutes. These concepts explained above are illustrated in Figure 1 below.

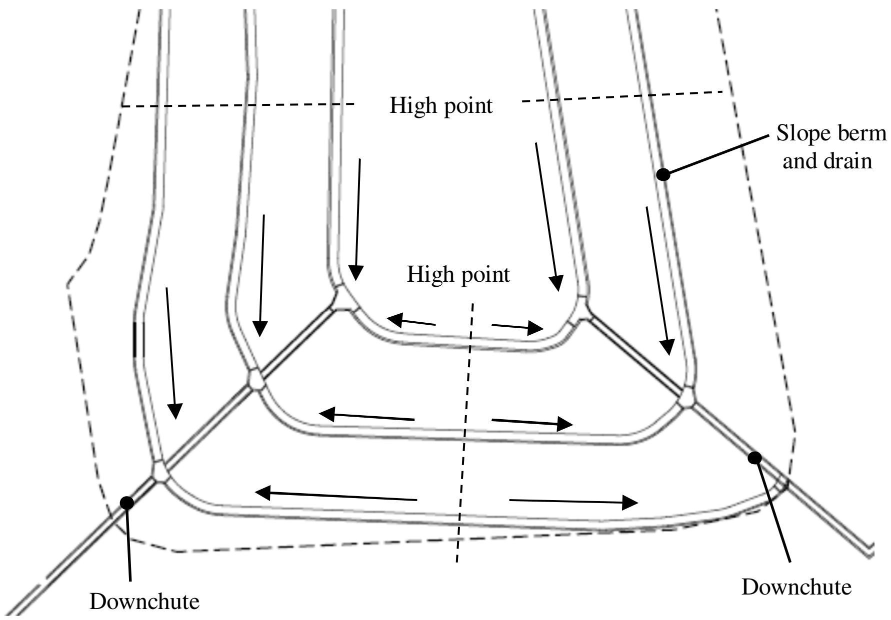

Figure 1. Storm water management on final landform.

3.3 Capping design

The proposed capping layers were designed in accordance with the Minimum Requirements for Waste Disposal by Landfill, 2nd edition (1998). A ferricrete protective cover layer was placed over the final waste surface and will serve as the required foundation layer for the start of the capping layerworks. The capping layers consist of three 150mm compacted clay liners above a geocomposite drain which is placed over the ferricrete protection layer. The compacted clay layers are required over the geocomposite drain to limit infiltration into this drainage layer. The capping layers are covered by a 200mm thick layer of topsoil to reduce the desiccation potential of the clay cap and to provide a suitable growth medium for the vegetation. The capping design is shown in Figure 2.

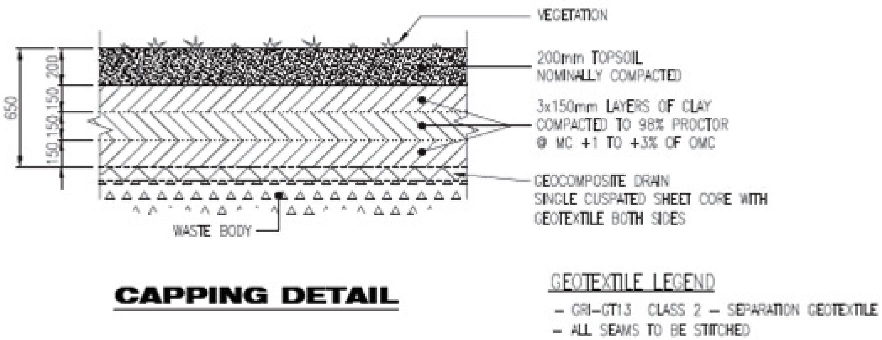

Figure 2. Capping design.

3.4 Geosynthetics

The use of a geocomposite drainage product with a cuspated high density polyethylene (HDPE) core and geotextiles bonded on either side is incorporated in the capping design. This product serves several purposes: it limits the quantity of precipitation that enters the waste by providing a capillary break layer to significantly reduce infiltration, it acts as a drainage layer, and the geotextiles provide protection to the HDPE core as well as a filter to over- and underlying materials. An important aspect of geocomposite drains is the quality of bonding between the geotextiles and HDPE core, which is required to ensure long term veneer stability of the cap. As highlighted in literature review, for the sizing of the geocomposite drain the following inputs were considered:

- reported flow capacity for the geocomposite drains at 1 in 3 (side slopes) and 1 in 20 (plateau) slopes,
- expected overlying pressures from the soil layers and construction plant,
- recommended reduction factors according to Koernor (2005),
- the permeability of the overlying soil as determined by laboratory testing, and
- slopes lengths as well as lengths between drainage pipes.

Furthermore, it is important to compare the characteristics of the geotextile with the overlying material as the filter compatibility requirements is a critical part of the geocomposite drainage design. It may even be necessary to specify the apparent opening size of the geotextile to ensure that no clogging of the geocomposite drainage product will occur.

Suitable rehabilitation would be achieved by the construction of an effective landfill capping system, with consideration of appropriate vegetation. Erosion control blankets were used on the plateau and side slopes drains to assist with the establishment of vegetation by increasing the resistance to flow and preventing soil erosion.

3.5 Practical construction

As described above, the design of geocomposite drain is governed by the distance between drainage pipes – these were installed underneath each slope drain and the typical detail as can be seen in Figure 3. The drainage pipes are placed in a 300mm deep trench surrounded by 19mm stone. Although geocomposite drain products can be manufactured to have long enough lengths that could span the entire side slope, the design specified that the geocomposite drains terminate in these trenches. This is also where the next panel for the proceeding slope is secured. These trenches offer anchorage of the material for the slope length and by shortening the slope lengths as well as specifying these discrete slope distances from anchor trench to anchor trench, reduces the risk of a catastrophic failure if one of the panels were to pull out. Figure 4 is a photo from the site where the geocomposite drain is draped through the anchor trench and slightly past to ensure that it is cut at the correct position.

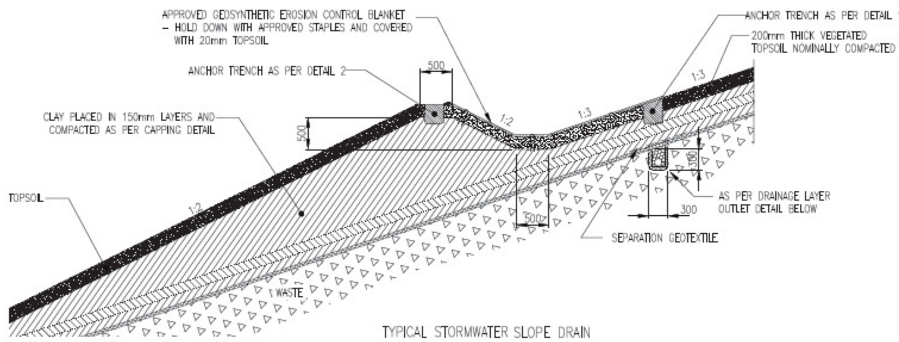

Figure 3. Anchor trench for geocomposite drain under slope drain.

Figure 4. Installation of geocomposite drain in anchor trench.

The combination of the gradient of the side slopes and the small volume of stone required over a long length, presented a challenge for the placement of the 19mm stone into the trenches. Since the stone could only be stockpiled on the plateau, as this was the first portion of construction to be completed, the best solution was to create a chute type of system that could convey the stone from the top of the landfill to the trenches on its slopes – see Figure 5. This proved to be efficient as it resulted in the shortest travel distance with the chute pivoting around from a top central position.

Figure 5. Chute for 19mm drainage stone installation.

Geotextiles have been known to have a low UV resistance and thus the geocomposite drains had to be kept rolled up as long as possible to limit the geotextiles' exposure to the sun (UV degradation). On the plateau was not problem due to the gentle slopes but once on the side slopes this was no simple task. An onsite innovative solution had to be made – Y posts were driven through the protection layer and deep into the waste behind the rolled up geocomposite drain to keep it in place as shown in Figure 6.

Figure 6. Solution for keeping rolls of geocomposite drain in place on side slopes.

Geojute was used for erosion protection on the drains on the plateau and side slopes. To ensure intimate contact, the erosion control blankets were stapled to ground using U-shaped pins. A thin layer of topsoil was then placed over the blanket which shields it from sunlight and reduces degradation. Additionally, once the vegetation starts to grow, the root system will become entwined with the jute providing reinforcement and further protection against occurrences such as a rain event. Figure 7 is a photo of the geojute installed on a slope drain on site prior to the placement of the topsoil.

Figure 7. Erosion control blank on slope drain.

4 Conclusion

Suitable rehabilitation can be achieved by the construction of an effective landfill capping system, with consideration of appropriate water management and establishing vegetation. The paper illustrated that geosynthetics can be utilized for drainage and erosion control in a landfill capping system. From this paper it is clear that the geocomposite drains need to be adequately design to ensure there are no excessive seepage forces that could cause instability. Furthermore, erosion control blankets support the vegetating of the cap by preventing erosion and improve the aesthetics of the site.

In conclusion, this paper detailed the capping system that was implemented, highlighting the solutions developed on site to simplify the construction, to achieve effective closure and rehabilitation of a hazardous landfill.

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