A geosynthetic alternative to traditional sand filter drains in a piggy-back tailings storage facility

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INTRODUCTION

The processing of most mined metal ores results in waste commonly known as tailings. The sheer volume of tailings and their potential environmental impact necessitate engineered disposal techniques and storage facilities. The dam walls for third and fourth generation type facilities are constructed using the tailings themselves for cost effectiveness. These facilities can follow three main construction methods, namely upstream, centreline or downstream development of the walls. Irrespective of the construction technique utilised, the principle is to create a consolidated stable outer annulus to contain the inner saturated, often under-consolidated, core. Creating the consolidated outer annulus is facilitated by the inclusion of filter drains – often called under drains – around the perimeter to draw down and control the phreatic surface emanating from the flow or seepage of pore water from the saturated core. Apart from the aesthetic aspects and their impact on the environment, tailings dams are often extensive in area, sterilising valuable land. Consequently, it is becoming increasingly difficult to license new tailings storage facilities (TSFs).

Piggy-back TSFs aim to reduce the footprint of the tailings facility by building 'up' rather than 'out'. They are constructed on top of existing tailings dams. Some old tailings dams may not have had any under drains, or may just be too high or old for the original ground level filter drains to be effective in controlling the phreatic surface within the piggy-back tailings to be deposited on top. Regardless of the method employed to construct these facilities, the piggy-back deposit requires under drains of some form to maintain a low phreatic surface in the dam to facilitate consolidation and improve stability of the dam wall, and to reduce the recharge to the underlying tailings, which could otherwise cause seepage and instability in the hitherto stable old slopes. These drains are typically constructed using selected filter sand, clean single-sized stone, and slotted pipes. Transporting this material to the top of an existing dam that may still be operational, can be onerous and can also cause disruptions to the normal operations of the facility, as surfaces need to be allowed to dry and consolidate for loaded construction equipment to gain access to place the sand and stone.

GEOSYNTHETICS

As defined by the International Geosynthetic Society: *geosynthetics are planar, polymeric (synthetic or natural) material, used in contact with soil, rock and/or any other geotechnical material in civil engineering applications.*

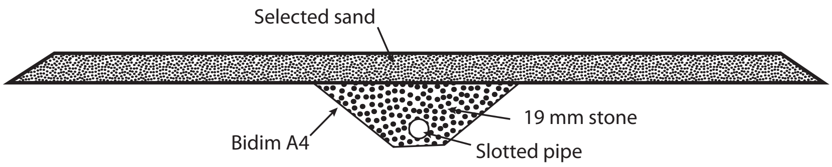

Figure 1 Typical design of conventional filter drain

In the early 1970s Bidim® geosynthetic filter fabric was introduced to the South African civil engineering industry. After the first earth dam was constructed using geotextiles in 1970, at Valcros in France, many designers adopted a simpler drain design wherein the filter fabric replaced many layers of the natural filter material. Since 1975 geotextiles have been used successfully in large dams in South Africa, including the 51 m high Kilburn Dam, the 56 m high Mokol Dam and the 43 m high Kwena Dam, amongst others. The geotextiles were used downstream of the chimney drain, as a supplement to the granular filter system on either side of the clay core, beneath rip-rap, surrounding toe drains and blanket drains.

Considering the escalating cost, increased scarcity and effort required when using natural material for the construction of filter drains, an opportunity was identified to develop a composite geosynthetic filter drain which does not require any natural filter sand or stone.

CHEMWES AND CROWN TSF – PROBLEMS EXPERIENCED

The Chemwes No 5 TSF, on the West Rand, was an existing operational facility being developed at a relatively high rate of rise (ROR) of 3 m/yr. An extension of the life and expansion of the operation called for an interim tailings disposal solution requiring an 8 m/yr rate of rise. The high rate of rise dictated the use of cyclones to deposit an outer wall which, due to its inherent higher permeability, required under drains to control the seepage, thus preventing the development of excess pore pressure.

Many difficulties were experienced while trying to install the filter drains, due the facility being operational at the time. The natural drain materials, sand and stone, had to be transported up to the top of the existing dam to sections where the tailings had to be allowed to dry for weeks to achieve the required minimum bearing capacity to carry the fully loaded trucks. It was this experience that highlighted the need for an alternative system of under drains that did not require any natural filter material.

The Crown TSF had previously retrofitted geotextile-wrapped 'sausage' drains, comprising perforated collector pipes encased in stone, to control slippages. These have been used with sustained success, indicating the durability of the geotextile against acid attack and clogging.

BRAKPAN TSF

Brakpan TSF handles gold tailings from the Ergo complex. Tailings usually fall within the 60 micron to 300 micron particle size bracket, corresponding to a fine to medium sand fraction, and are typical of Witwatersrand gold tailings underflow. A piggy-back TSF of 40 m high was required to be built on top of the existing 80 m dam, but the designers were reluctant to repeat their experience on the Chemwes site. A solution was required that would not necessitate stone being transported to the top of the existing dam, and that could be installed with little effort, while making minimal use of earthwork equipment. The success of the Crown 'sausage' drains pointed towards developing a composite geosynthetic filter drain.

Tailings/geotextile compatibility

Before the composite geosynthetic drain could be assembled, the tailings from the Brakpan TSF had to be evaluated with regard to compatibility with the candidate geotextile filter. This was required to ensure that the geotextile would not blind or clog, and that piping would not occur. These are the main mechanisms of failure of geotextiles and have resulted in some

The cost comparison showed a 20% saving in the cost of the composite geosynthetic filter drain compared to the conventional sand/stone filter drain. This did not account for escalation over the 20 months between the pricing exercises which could have increased the savings in real terms. An additional and decisive factor that should be borne in mind was the ease of installation with minimal disruption to the on-going tailings deposition on other parts of the dam, improving quality control on the drain installation and minimising the risk substantially on the deposition operation

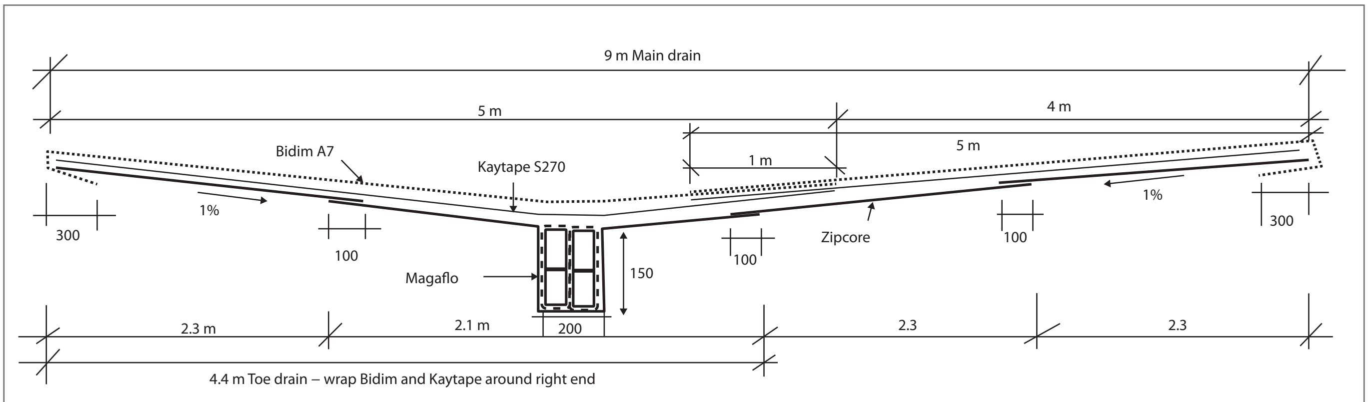

Figure 2 Detail of composite geosynthetic drainage system

engineers being circumspect about the use of geotextiles as filters. Such a failure could have a severe effect on slope stability and could limit the maximum height of the dam. These conditions are influenced by the apparent opening size (AOS) of the pores in the geotextile in relation to the material being retained. This is a function of the approximate size of the largest particle that will pass through the geotextile.

The permeability of a geotextile filter can be significantly reduced over the lifetime of the installation. For this reason a geotextile with permeability ($\mathbf{k}_g$) of at least 10 times the permeability of the base soil ($\mathbf{k}_s$) should be specified.

Long-term gradient ratio (LTGR) test

The LTGR test, which is based on the gradient ratio test (ASTM D 5101), uses a customised permeameter fitted with standpipes to measure the changes in hydrostatic head across a soil sample and the soil/geotextile interface below. Water is passed vertically through the sample of soil to be drained on site and the candidate geotextile as setup in the permeameter. Changes in flow rate and standpipe readings are taken periodically. Using Darcy's equation the permeability of both the soil and the soil/geotextile interface can be calculated.

After performing a desktop analysis based on the particle size distribution of the Brakpan TSF tailings, two grades of nonwoven geotextile were chosen for testing. The choice of these grades was based on an optimisation of the filtration characteristics influenced by the thickness and number of constrictions of the geotextile.

The nonwoven geotextile selected for use in the trial section maintained a higher flow rate, indicating higher permeability with a gradient ratio (GR) of around 1.4. A GR between 1 and 3 indicated that the soil sample was stable and the geotextile was working satisfactorily. A GR of >3 indicates a clogging potential, whereas a GR value of <1points to a piping problem. The 6% of clay and silt size particles in the sample led to a small amount of piping, which was reflected in the conductivity readings. Once these fines had migrated through the geotextile, a more open filter bridge was developed and stability was achieved.

The nonwoven geotextile selected also satisfied the conditions of the desktop analysis, having an $\mathbf{O}_{95W}$ = 100 µm and a permeability of $\mathbf{k}_g$ = 4.8 × 10^{-3} m/s more than 900 × the permeability of the soil $\mathbf{k}_s$ = 5×10^{-6} m/s.

Composite geosynthetic drainage system

The proposed composite geosynthetic drainage system consisted of two 170 mm high MegafloTM panel drains installed vertically next to one another to maximise compression resistance against the increasing overburden pressure. These drains were supplied pre-wrapped in a nonwoven geotextile and had a combined width of 100 mm. A cuspated solid sheet geospacer, ZipcoreTM, formed the base of the drainage system. Made from a sheet of HDPE this formed a cut-off barrier and conduit to contain and direct all the moisture that was collected by the drain to the MegafloTM collector pipes. The geospacer was laid with a slight fall towards the panel drains. A high-strength slit-film woven tape geotextile, Kaytape® S270, was laid directly onto the geospacer to act as a bridging medium over the 8 mm high cuspations. This allowed for a high confining pressure to be accommodated by the drain without a loss in lateral flow capacity. The nonwoven geotextile was then laid on top and acted as a filter, as depicted in Figure 2.

This innovative composite geosynthetic system facilitated the quick and easy installation of the drain with minimal earthworks and no imported filter sand or stone. The tailings were deposited directly onto the drain.

Cost analysis

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An additional and decisive factor that should be borne in mind was the ease of installation with minimal disruption to the on-going tailings deposition on other parts of the dam, improving quality control on the drain installation and minimising the risk substantially on the deposition operation.

Test section – Brakpan TSF

A 40 m long, 5 m wide section of the composite geosynthetic filter drain was installed at the Brakpan TSF. Paddock walls lined with HDPE were constructed around the test panel to allow the filter to be covered in four 1 m layers of tailings in a relatively short period of time to simulate the intermittent but progressive development of a tailings dam. An outflow pipe from the test panel was installed to enable the measurement of the outflow rates from the drain. The drain's ability to withstand the intended 40 m overburden stress was also assessed.

The measured flow rates as shown in the graph in Figure 3 demonstrate an initial surge when the tailings were deposited, then a gradual decrease in flow until the next layer had been deposited. The fact that the flow rates surged each time a new layer of tailings was added indicates that the drains had not been compromised and that the geotextile filter had not blinded or clogged. The lower peaks and the sustained

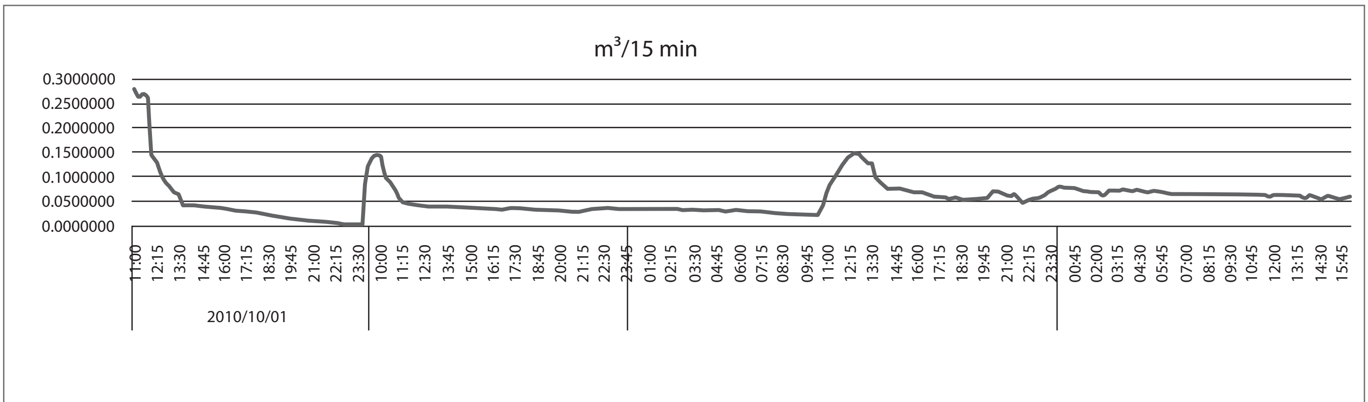

Figure 3 Flow measurements from outlet pipe

longer continuous flow are indicative of the greater depth of tailings deposited over the drain with each cycle.

CONCLUSION

Based upon the cost effectiveness, installation advantages and the positive test results, 8.5 km of composite geosynthetic drains are being installed on the Brakpan tailings storage facility. These benefits of the composite geosynthetic drainage system have led to the same system being implemented on two new TSFs on ground level at two chrome mines, with a third currently under design.

Nonwoven continuous filament filter fabrics have been successfully utilised in the South African civil engineering industry for more than 40 years. Over this time there has been evidence that not all tailings are compatible with geotextile filters, but this project has shown that, with the correct laboratory testing, desktop analysis, specifications and field trials, geosynthetics can be used to great effect in facilitating the drainage of tailings deposits..

REFERENCE

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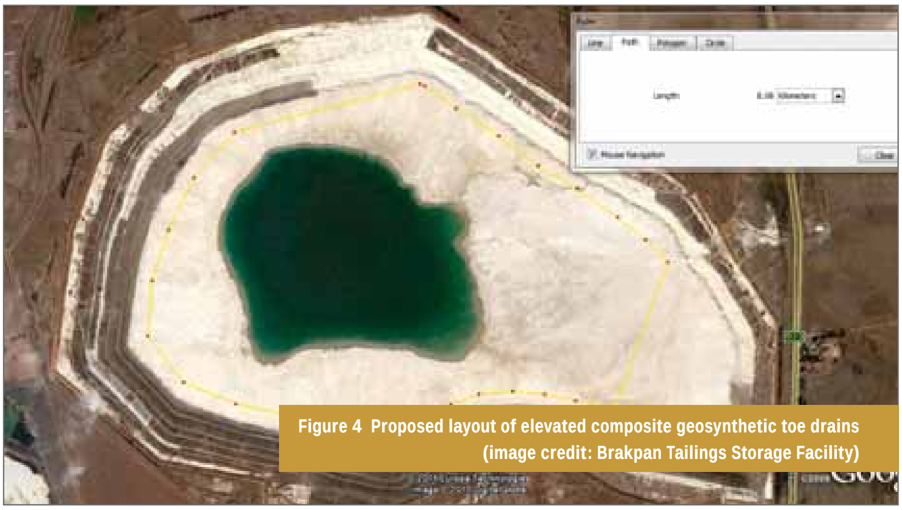

Figure 4 Proposed layout of elevated composite geosynthetic toe drains (image credit: Brakpan Tailings Storage Facility)

No tailings facility, irrespective of size, location or geometry, should be designed in an off-the-shelf manner. Each tailings facility, and the operator/owner of that facility, deserves a design that is an appropriate reflection of the prevailing site conditions and the breadth of potential operating constraints to which the facility will be subjected. Any lesser design stewardship is deficient (Martin *et al* 2002)

Figure 5 Composite geosynthetic drain specified for non-elevated applications due to success at Brakpan TSF (image credit: Lannex Tailings Storage Facility)

Source:
http://www.saice.org.za/downloads/monthly_publications/2012/2012-Civil-Engineering-April/#/0