Proceedings Tailings and Mine Waste 2011
Vancouver, BC, November 6 to 9, 2011

Geotextile Enabled Smart Monitoring Solutions for Safe and Effective Management of Tailings and Waste Sites

Two case studies: Volgermeerpolder (The Netherlands) and Suncor (Canada)"

Rob Dijcker, Marten Van Der Wijk

Witteveen+Bos Consulting Engineers, Deventer, The Netherlands

Olivier Artières, Gerrit Dortland,

TenCate Geosynthetics Europe, Almelo, The Netherlands

John Lostumbo

TenCate Geosynthetics North America, Pendergrass, USA

Abstract

Numerous accidents at tailing disposal sites have occurred due to dam failure and geotechnical instability. The uncontrolled spreading of pollution into the surrounding environment, illustrates over and over again the need for safe and effective management of these kinds of sites. Safe and effective management measures can only be implemented on the basis of a thorough understanding of the physical, chemical and biological processes taking place at the tailing facilities. After implementation of the necessary measures, ongoing monitoring can verify the proper functioning of the rehabilitated tailing disposal sites. Assessment and evaluation of historic tailing facilities has shown a need for improved monitoring concepts and techniques. In this paper the authors present a new monitoring technique which meets the needs for safe and effective monitoring and can be applied within a smart monitoring concept.

Introduction

Due to their extensive occurrence and persistent nature, solid mine waste and mine tailings are ranked amongst the world's largest environmental problems. The uncontrolled dumping of waste and/or insufficient aftercare has already caused several accidents at tailing disposal facilities throughout the world. Not only in the past, but also recently (e.g. the tailing dam failures in Kolontar, Hungary (October, 2010) and Kütahya, Turkey (May, 2011)). Even when major failures have not occurred, deposits of mining waste can cause severe environmental impacts by acidification of drainage water and/or surface erosion by wind loading the surrounding environment with metals. The mismanagement of (old) mine waste and tailing facilities is not only causing environmental problems, but can also have a seriously negative impact on the economy due to high costs for rehabilitation, issues of liability and responsibility, and last but not least the declining image of the mining industry. Therefore, there is an urgent need for cost-effective and sustainable solutions for the management of waste and tailings.

Risk assessment and planning of remedial action for multiple tailing sites requires addressing challenges with: dam stability, (bio) remediation, risk analyses, monitoring and re-mining. It is of utmost importance that the actual risks and the governing processes (physical, chemical, biological) be thoroughly understood within the frame of a site conceptual model to be able to predict future development of tailings sites. Once these processes become predictable, the optimal moment for remedial actions can be determined and implemented at the right time.

A well defined monitoring program based on the concept of early warning and adapted to the local conditions, is a precondition for implementing a cost-effective site remediation plan. Monitoring and development of the conceptual site model for tailings dams and ponds requires a variety of specialized know how and instrumentation. The monitoring solution combined with this model requires robustness and high sensitivity in these sometimes aggressive environments. The use of a sensor enabled, fibre optic geotextile composite meets these requirements to assess important structural parameters such as soil strain or temperature change.

This paper presents the application and performance of fibre optics for monitoring of the capping in the case of two different projects recently installed: the landfill Volgermeerpolder, Amsterdam (case 1) and the Suncor #5 tailing pond, Canada (case 2).

The fibre optics monitoring solution

This monitoring solution combines geotextile composites, fibre optics sensing technology, instrumentation equipment and data acquisition software. By utilizing fibre optic sensing technologies, such as Fibre Bragg Gratings which measures very narrow optical index changes written at given locations inside the optical fibre line for point specific measurements, or Brillouin and Raman technologies which provide distributed measurements at any point along the optical fibre, we are able to measure very precisely soil parameters such as temperature or strain under static or dynamic conditions.

Fibre optics have been widely used for many years in civil engineering applications, specialty pipelines, structural health monitoring systems or hydraulic works applications such as concrete and earth dams, levees and dikes. By embedding optical fibres onto a geotextile fabric (Figure 2), TenCate GeoDetect® is the first system designed specifically for geotechnical and hydraulic works applications. The geotextile fabric, e.g. a textile installed in the soil, enhances its mechanical and hydraulic properties by in-plane drainage capability, excellent anchoring interface with the soil, soil reinforcement, separation and filtration.

For example the drainage properties of the geotextile combined with the temperature measurement with the optical fibres improves the speed of leakage detection. If a leak occurs away from the optical fibre, it can be collected and drained through the plane of the fabric faster than flowing through the soil only. The filtration properties of the geotextile also increases the stability of the soil by inhibiting the internal erosion process.

Another benefit of using a senor enabled geotextile is its high interface friction properties with the soil. With the geotextile being securely anchored in the soil, and the strong connection between the optical fibre and the geotextile, even very small soil strains can be detected. This friction interface also facilitates the transfer of soil movements from the geotextile to the fibre optic line.

This sensor enabled geotextile is designed to detect temperature and strain at the same time. Using the passive method or the active heat pulse method, water leakage, which is the main cause of internal erosion, is assessed through the measurement of temperature changes. Water temperature is different from the soil temperature and creates a perturbation of the temperature profile when water flow occurs. First stages of soil movement, settlement or sliding are detected by strain measurement. Measuring at the same time and at the same location both temperature for leak detection and soil strain for soil movement detection increases the probability of obtaining the right precursors of a malfunction.

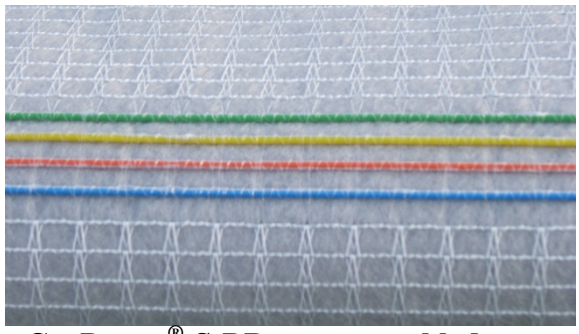

Figure 2: The TenCate GeoDetect® S-BR sensor enabled geotextile embedded with 4 optical cables, 2 for temperature measurement and 2 for strain measurement

The monitoring and early warning system

Combined with the appropriate software and instrumentation (Figure 3), the monitoring system provides an innovative solution for the multi-functional requirements of geotechnical and hydraulic applications in addition to data capture.

Different monitoring strategies may be incorporated into the design. Either periodic or continuous monitoring can be used as an early warning system.

In comparison to existing detection systems made of local and individually wired sensors, this solution measures continuously hundreds to several thousands points with a single system along the full length of the hydraulic structure. This increases the accuracy and the speed of response, both crucial parameters to prevent collapse. It can provide leak and deformation location with a spatial resolution of 1 meter, or even 0.5 m in some cases. The system is able to monitor several tens of kilometres.

Once installed, the sensor enabled geotextile communicates the soil strain and temperature data to the system's instrumentation equipment. Soil strain as low as 0.02% can be measured, and with the proper software, changes in temperature can be monitored at 0.1°C with a spatial resolution as precise as 0.5m to 1.0m.

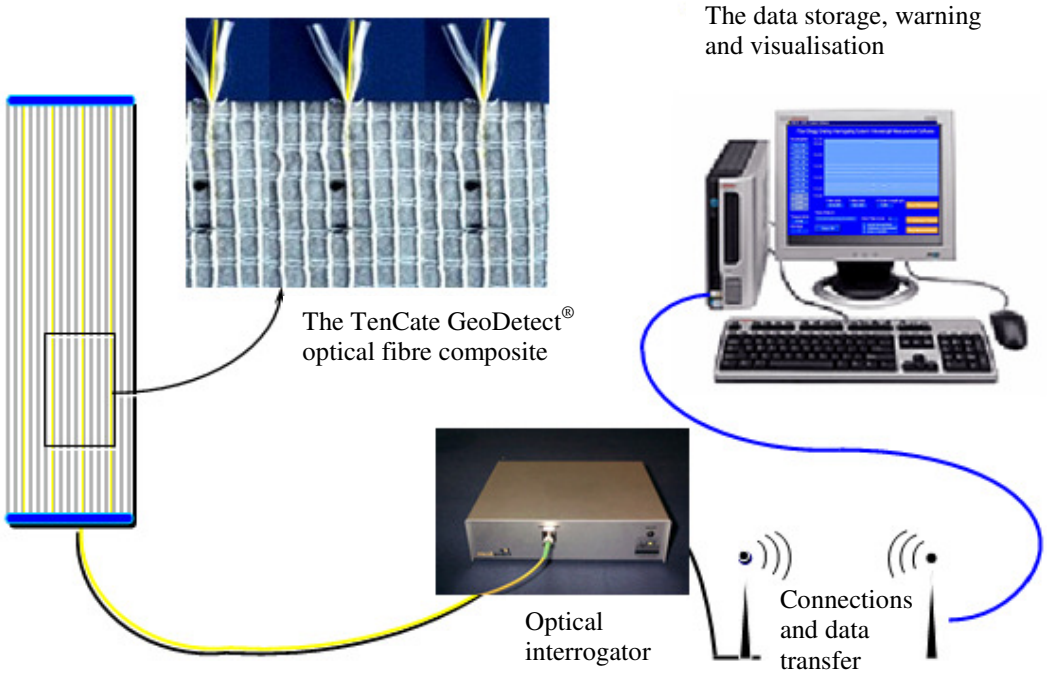

Figure 3: The TenCate GeoDetect® system components

Case 1: Landfill Volgermeerpolder, The Netherlands

Site description

The Volgermeerpolder is an area of approximately 105 ha, which in the twentieth century was used as a dump site for large quantities of chemical waste, including 30,000 barrels of pesticide production waste, resulting in one of the most contaminated areas in Western Europe. The Volgermeerpolder is located 5 km north of the city of Amsterdam, in a marshy polder with shallow groundwater, open water and a deep peaty soil.

Rehabilitation works

The remediation of the Volgermeerpolder started in 2005, with covering the landfill with various surface sealing layers. The first layer consists of soil from ground works in the region, which is then covered with High Density Polyethylene geomembrane On top of this HDPE geomembrane a second soil layer is placed. The existing waterways are also covered with HDPE geomembrane and soil. On the 60 ha wet low-lying areas a wetland is created, by making a system of shallow ponds – 59 sawa's and the existing waterways – with dikes on top of the soil/HDPE cover. The remaining 40 ha is considered a dry area. As part of the remediation a buffer zone is created around the Volgermeerpolder in which the groundwater quality is extensively monitored. The capping of the Volgermeerpolder was completed in 2010.

Monitoring of the capping liner

Introduction

Landfill capping is often challenging. Creating a watertight liner on top of heterogeneous and compressible layers of waste or subsoil is not easy. In these conditions, landfill capping with a natural clay layer is inappropriate for long term water tightness due to the cracks that may appear when submitted to differential settlements. The geomembrane lining system is an appropriate alternative compared to clay layers as geomembranes are flexible. They can follow, to a certain extent. the movement of the sub layers. When unstressed and protected from UV, polyolefins are chemically stable polymers and can last for decades. However, settlement may create tensile strain in the geomembrane. Polyolefin geomembranes, such as HDPE, are sensitive to stress cracking when strained above several percent points for a long period. The permanent stress creates micro cracks in the polymer which may increase the ageing speed and reduce the product durability. It is thus important to monitor the strain occurring in the lining system.

Due to the compressible nature of the subsoil and of the waste, settlements are expected. A particular need on this site was to assess the geomembrane strain due to the increase of normal load from the sand and the water on top of it. But strain measurement in soil with local conventional sensors is often difficult due to installation and reliability problems. For this purpose, it was decided to use the TenCate GeoDetect® fibre optics monitoring solution.

Installation

One pond lined with a geomembrane was covered with a continuous strip of the TenCate GeoDetect® S-BR fibre optics geotextile to follow the movement of the geomembrane. They were laid continuously on the top of the geomembrane (Figure 5), below the sand layer, in several "S" shapes crossing the area from several sides of the pond. This continuous strip makes large loops at the top of the basin dikes to create strip anchoring on the side and to have fixed reference points to measure differential strain. The slopes of the pond are lined with a rough geomembrane which increases the friction and the anchoring

of the nonwoven based textile strip. The strip is connected to an optical distributed Brillouin interrogator placed inside the main building with a 200 m long optical junction cable. The total strip length is 425 ml (Figure 6).

Figure 5. Volgermeerpolder: unrolling the sensor enabled geotextile strip on top of the geomembrane

Figure 6: Volgermeerpolder: Pond lined with the geomembrane covered with several sensor

enabled geotextile strips.

Results

The sand layer cover was laid into the pond a few days later (Figure 7). We observed immediately an increase of strain where the sand was placed. The resolution of the reading was less than 0.1%. The measured strain values have reached 2 % in several locations, for example at the toe of the slope, where the differential settlement between the dike and the waste body is high (Figure 8). Since installation, the variation speed is slower, as a result of the increase in water height from the rainfall in the basin which is a slow process. The last periodic measurement took place in springtime 2011 and has shown

stabilization of the strain (Figure 9). The maximum strain measured remained below the 2.5 – 3 % required to prevent any risk of stress polymer degradation.

Figure 7: Volgermeerpolder: Covering with 1 m thick sand layer

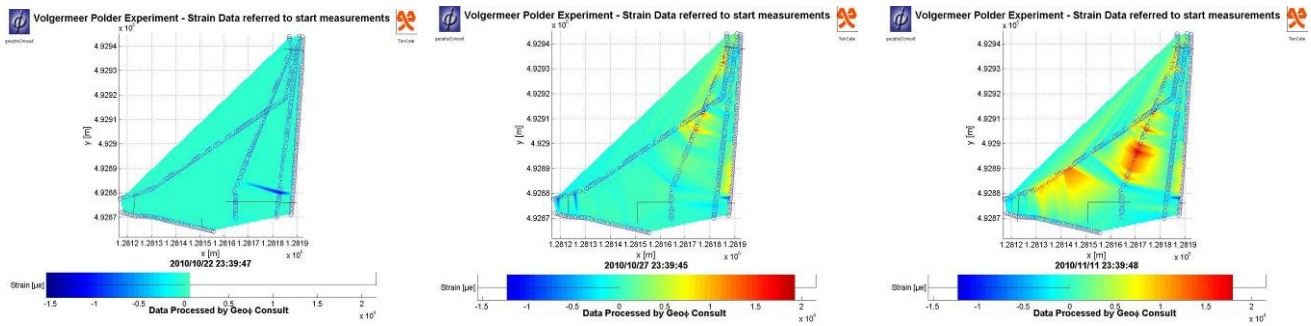

Figure 8: Volgermeerpolder: Evolution of the strain measured on 22/10, 27/10 et 11/11/2010 from the left to the right – Scale in %.

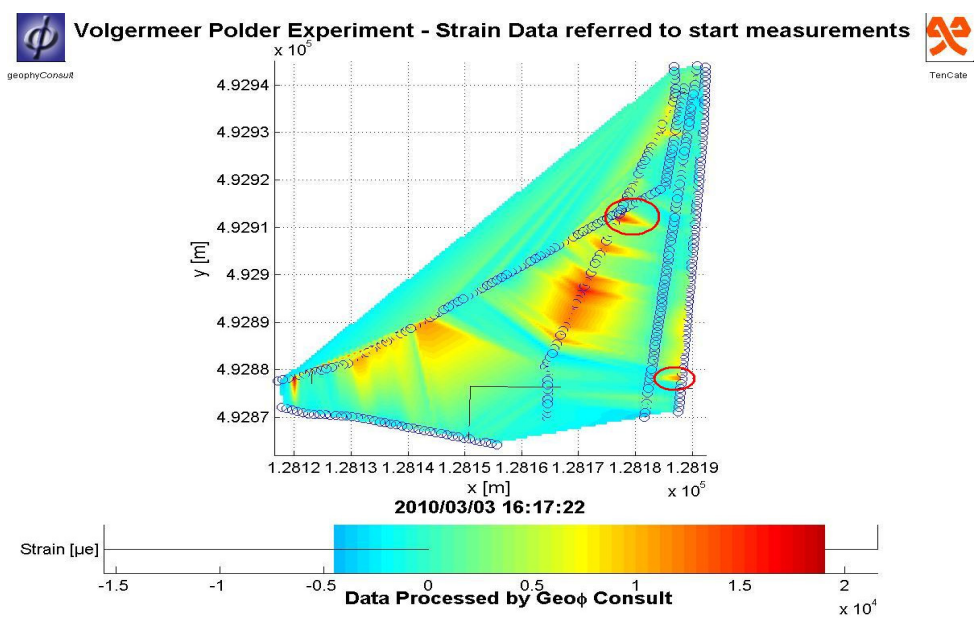

Figure 9: Volgermeerpolder: Strain measured on 03/03/2011 from the left to the right – Scale in %.

Case 2: Suncor Pond #5, Canada

Site description

Suncor Pond #5 north of Fort McMurray, Alberta, Canada is a tailings waste pond approximately 3 km by 5 km in size. Suncor plans to close and reclaim the pond area by 2019. A soft cap utilizing high strength geotextiles was selected for the closure. High-strength geotextiles have been used for sludge pond capping projects throughout North America on a variety of industrial waste sludge material. Pond #5 will be a very large scale project using this technology.

The tailings in the pond are highly variable with extremely low strengths. Shear strength of the near surface tailings is less than 1 kPa. In addition, during the several year reclamation project, it is desired to use portions of the pond cap for trucking and hauling material at the site. This will require the cap to be able to support fully loaded mining operation size dump trucks. Design of the tailing pond cap utilized a high strength woven polypropylene geotextile, with ultimate tensile strengths of 105 kN/m by 55 kN/m. The high strength geotextile is seamed together to provide reinforcement and support of the cap material. A geogrid was placed on top of the geotextile, perpendicular to the seams to help prevent overstressing at the seam locations.

A monitoring program was developed for the project to verify the design and performance of the system. The monitoring system included the use of fibre optic sensors embedded into a geotextile for strain monitoring of the geotextile reinforcement material. The unique ability of the fibre optic sensors embedded in a geotextile material allowed for quick and easy installation of strain sensors in a harsh and extremely cold weather environment.

Monitoring and results

Readings from the fibre optic sensors were taken manually at the site during fill placement and with truck traffic. The fibre optic sensors showed strain values less than 1% strain in all areas utilizing the fibre optic geotextile. Readings ranged from approximately 0.2% to 0.85% strain. This verified that the geotextile was not being over stressed and was working as designed and below the critical design strain of 5%. Utilizing the fibre optic sensors allowed for evaluation of the design and potential optimization of the design for the remaining capping areas at Pond #5.

Smart monitoring of mine tailings

Deposited mine tailings form a complex system of interacting geochemical, physical and biological processes. With the progress of time, the tailings evolve, going through several stages and creating new and different risks. This makes the management of mine tailings, specially on the long term and with limited resources, a real challenge. Better insight in current and future behaviour of tailing material is an essential step to come to more cost-effective, reliable and robust rehabilitation solutions for mine tailings.

The two cases has shown that the use of advanced and real time monitoring techniques like fibre optics can provide a better understanding of behaviour of the capping liner and the waste below. However, the geotechnical stability is only one element of the different processes that play a role at mine tailing sites. For example the production of acid rock drainage (ARD) can cause severe problems for water quality. To improve the understanding of the complex system of interacting geochemical, physical and biological processes the concept of Smart Tailings can provide new chances for enhanced monitoring quality. This concept emphasizes new and innovative measuring and monitoring techniques that are integrated into one platform for integrated and real time monitoring of mine tailing sites and effective management of the resulting data. Most of these measuring and monitoring techniques have proven

their performance and effectiveness in other fields than mining, like flood protection, biotechnology, archaeology and environment. As the monitoring systems become an integral part of the remediation design, application of the concept will generate a real-time data flow, allowing for the creation of an early warning system and support for better management decisions. Both presented cases show perfected examples of a technique which can be applied within this platform.

Improved understanding of the processes occurring in the deposited tailings and solid mine waste also opens possibilities for site specific and more sustainable solutions such as applying alternative soft covers , or the use of secondary or recycled mass streams that would otherwise be considered waste. Enhanced monitoring will show the sustainable feasibility of these alternative solutions.

Conclusions

The monitoring of the capping liner at the Amsterdam Landfill Volgermeerpolder and at the Suncor tailing pond #5 has shown that fibre optics embedded in geotextiles can provide accurate information on the behaviour of the capping liner and the waste below. Geotextile fibre optics is a perfect example of how smart monitoring solutions can contribute to a better understanding of the site conceptual model and at the same time act as an early warning system and support for better management decisions.

To utilize the full potential of the monitoring philosophy behind the fibre optics embedded geotextile (real time, online, great number of observation points) the concept of Smart Tailings is introduced. The innovative techniques applied within this concept should be adapted to the existing data management structures enabling integrated real time and online monitoring of tailing disposal facilities.