Use of Geosynthetics in the Mining and Mineral Processing Industry

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This article gives a brief overview and the results of research work conducted under the 2003 North American Geosynthetics (NAGS) "Award of Merit". The NAGS Award Program was initiated in 1989 as an industry sponsored program to recognize excellence in the state-of-the-art and state-of-practice related to geosynthetics research and applications in North America. A complete research report is given elsewhere and is entitled, 'Final Report on Use of Geosynthetics in the Mining and Mineral Processing Industry'. The report was submitted to NAGS in Dec. 2007 to meet the Award of Merit requirements.

The objective of the research work was to investigate the main uses of geosynthetics in the mining and mineral-processing sector and to summarize relevant field performance results and related technical factors. The work was limited in scope mainly to polymer-based geosynthetics, including polyethylenes (PEs) and polypropylenes (PPs), but excluding polyvinyl chloride (PVC) formulations. Geosynthetic clay liners were also investigated to some extent.

At mine sites, geomembranes (GMs) have been primarily used as basal liners for heap leach and liquid containment facilities (drainage waters, process solutions, treatment ponds), and to some extent, for tailings and other solid waste storage facilities. Geogrids have been used to stabilize soft soils for road construction and mine tailings for placement of cover soils. Geopipes have been used for conveyance of runoff, drainage, and process waters; and/or for leak detection systems around mine sites. Table 1 summarizes common types of geosynthetics and their application in the mining and mineral processing industry.

The following is an outline of the final research report prior to the presentation and discussion of key study results. The final report commences with a listing of eleven typical environmental design constraints for mine sites, such as dam and slope stability, Acid Rock Drainage (ARD), and metal leaching (ML) control. ARD is a major problem facing the mining industry. ARD and common mitigation strategies are appended to the final report for the benefit of readers who are unfamiliar with the topic. For mine sites, the duration of responsibility and/or the post closure period may extend over several decades and even centuries, especially for sites with acid generating or radioactive wastes.

Chapter 2 of the final report contains a brief review of major characteristics of polymer-based geosynthetics and the calculation of the antioxidant depletion rate. It also describes technical considerations and related ASTM guidelines for the construction with polymer-based geomembranes.

Chapter 3 presents the following case studies and research results for polymer-based geosynthetics installations:

1. Use of geosynthetics in heap leach operations;
2. Use of LLDPE geomembranes to cap acid generating waste rock;
3. Use of a geogrid to stabilize soft tailings;
4. Use of a HDPE cover system over acid generating tailings;
5. Installation of a bituminous liner; and
6. Effects of synthetic acid rock drainage (ARD) on polymer properties.

Chapter 4 summarizes characteristics of Geosynthetic Clay Liners (GCLs). It also includes technical considerations and related ASTM guidelines for the design and construction with GCLs.

Chapter 5 includes the following case studies that illustrate GCL applications:

1. GCL Cover on Apache Tailings near Leadville, Colorado;
2. GCL Cover on Zortman Landusky Suprise Pit near Landusky, Montana;
3. Performance of 45 cm landfill cover systems containing GCLs in a temperate climate near Hamburg, Germany;
4. Performance of 45 cm soil cover systems containing a GCL in a humid, northern climate near Stewart, British Columbia, Canada;
5. Panel Separation of GCLs below textured geomembranes that were left uncovered (at various landfill sites in the U.S.A.);
6. Laboratory Study of Gas permeability through GCLs;
7. Laboratory Study of GCL desiccation; and
8. Laboratory Study of Metal retention properties of GCLs.

Two of the GCL case studies pertain to landfill cover systems. These two studies constitute landmark studies and were included because one of their design objectives was to act as a hydraulic barrier, which is also a typical design objective for cover systems for mine waste.

Chapters 6 and 7 discuss study results and potential future developments.

KEY RESULTS AND DISCUSSION

Based on the reviewed case studies and related information, it was found that the mining and mineral processing industry is moving more and more towards the use of geosynthetics for civil, geotechnical and environmental engineering applications. The use of geosynthetics is evolving and their applications are gaining strides in the industry. Geosynthetic liners and collection pipes for heap leach operations are widely used and the adoption of higher and higher target heap heights is fostering the development of new design, laboratory testing, and construction methods. The duration of the service life of geosynthetics and their cost-effectiveness, when compared to other alternatives, are still the key constraints for their use in long-term geotechnical and environmental controls in the mining industry.

Due to their resistance to chemical attack and the low glass transition temperature of $-50^{o}C$ ($122^{o}F$), polyethylene (PE) geosynthetics have been the most widely used in the mining and mineral processing industries. Primary issues of concern for their use are physical and chemical compatibility with exposure conditions and adjacent materials. The service life of geosynthetics can be extended by subjecting the materials to less stress, lower temperatures, and fewer oxidizing agents. The service life of geosynthetics is very temperature dependent. For example, it was found that the theoretical anti-oxidant depletion time for HDPE coupons that had been fully immersed in synthetic acid rock drainage (ARD with a pH 2.1) ranged from 67.3 to 83.3 years at $20^{o}C$ ($68^{o}F$), compared to 3.7 to 4.5 years for synthetic ARD at $60^{o}C$ ($140^{o}F$) in one of the reviewed case studies.

The extensive use of HDPE and LLDPE geosynthetics in heap leach operations has demonstrated that they are suitable for containment of corrosive acid rock drainage and metal leaching products, at least in the short and medium terms and, also, under high heap loads. However, long-term performance data for the containment of high strength acid rock drainage / metal leaching waste does not exist. Available predictions have been based on a variety of laboratory tests and modeling to date. Theoretical service life estimates, based on laboratory testing, range from several years to centuries depending on the assumed predominant environmental exposure conditions. Currently, manufacturers are willing to warranty their products (materials and their replacement) for up to 20-30 years. Thus, there is a huge gap between the warranted service life and the required service life, at least for ARD/ML waste. For example, the required service life for ARD/ML waste is at least 100 years in Canada and the need for environmental protection may extend over centuries.

There is no doubt that decommissioning of operating heap leach facilities will be challenging, particularly for heap leach facilities that contain sulphidic ores and that are located in regions with a net annual water surplus. In facilities containing sulphidic ores, metals are extracted by fast tracking the generation of acid rock drainage. In an ideal decommissioning scenario in a region with a net annual water surplus, the heap leach liners may continue to function as hydraulic barriers while collection pipes will continue to collect leachate. If necessary, the leachate could be treated to meet receiving water quality criteria. In a less ideal decommissioning scenario, the heap leach liners and collection systems degrade and stop functioning. In this case, sophisticated waste and leachate management strategies may need to be implemented to protect the receiving environment, especially the groundwater and surface watercourses.

Cover systems that incorporate geosynthetics have been installed to control and possibly reduce the formation of acid rock drainage. Similarly, long-term performance data does not exist to evaluate its success in terms of mitigating ARD. The cover systems' longevity can be extended, if cover installations are designed and built by adhering to excellent QA/QC protocols and if chemical, physical and thermal stresses as well as exposure to oxidizing agents and UV radiation are minimized. In addition, the long-term stability of the soil cover (surcharge) that protects the geosynthetics has to be ensured to achieve a long service life.

The study on the use of LLDPE geomembranes to cap acid generating waste rock detailed an installation that focused on ensuring long-term slope stability and maximizing the service life of the LLDPE geomembrane. However, the final costs for the installation (that included resloping) of approximately US$807,500/ha (US$326,900/ac) should serve as a stark reminder to the mining industry and its consultants that planning for mine closure and appropriate waste placement at the time of waste generation is a good practice. It is important and cost-effective to design for closure!

The case study on bituminous liner placement demonstrated that liner installation is straightforward and that it could be accomplished even under unsteady weather conditions. The seaming of the bituminous liner was easily accomplished by a local roofing contractor following a brief training session on proper installation practices.

GCLs installed below geomembranes (GMs) to create a hydraulic barrier in cover systems have performed well at many locations. The cover systems' service life is limited by the longevity of the individual materials, the exposure conditions, and the quality of installation.

The performance of GCLs in liner systems (GCLs alone or below GMs) would depend on the pH, acidity/alkalinity, and cation concentrations in the contained liquid. Since bentonite typically looses its swelling capacity below pH 2, a GCL liner may fail when it is needed most to contain highly acidic solutions with a pH lower than 2. Ion exchange may also be an issue, because typical ARD has high concentrations of divalent cations such as Cu^{2+}, Zn^{2+}, and Pb^{2+}. The ion exchange of monovalent Na^{+} with divalent cations can lead to flocculation and hence to an increase in porosity and hydraulic conductivity. Thus, the performance of GCLs as hydraulic barriers in liner systems to mitigate acid rock drainage is uncertain. Further work is required to study the effectiveness of GCLs to mitigate ARD.

The suitability of GCLs to act as oxygen diffusion barriers (e.g. to mitigate acid rock drainage) is uncertain based on the case studies reviewed. The main shortcomings of GCLs include, but may not be limited to, a short oxygen diffusion path length and a relatively high susceptibility to desiccation.

The likelihood of temporary partial or complete desiccation of GCLs under field conditions appears high due to the following factors:

1. GCLs under shallow soil covers are prone to desiccation and ion exchange;
2. GCLs under thick soil covers are also prone to ion exchange (which may increase the GCL's effective porosity and effective oxygen diffusion coefficient) and, potentially desiccation;
3. GCLs below GMs are prone to desiccation if installed above drainage layers (as was demonstrated in one of the case studies); and
4. GCLs installed between two GMs would remain 'dry' unless one of the GMs leaks.

On the basis of the reviewed case studies, geomembranes such as HDPE and LLDPE may serve as hydraulic barriers in composite cover systems. Based on the literature reviewed, GCLs may be suitable as a hydraulic barrier, but may likely not be effective as oxygen diffusion barrier in cover systems.

POTENTIAL FUTURE DEVELOPMENTS

Applications of geosynthetics in the mining industry will likely expand in the future, at least for short- and medium-term applications. It would be mutually beneficial to the geosynthetics and the mining industry and other users to work together in order to track the performance of installations that are intended for long-term applications. It would be helpful to monitor and evaluate their performance on a regular basis. Results could be used to confirm predictions and improve product and/or installation quality as deemed necessary. These performance evaluations could be augmented by long-term laboratory tests to ascertain how well laboratory test results and field performance results agree.

Also, performance evaluations of geosynthetic materials that were exposed to heap leach solutions for extended periods (e.g. 2, 5, 10 years or longer) would be helpful in establishing timeframes for typical material degradation under field conditions. This information could be used to develop better materials, but also to develop maintenance and, if necessary, replacement schedules for materials prior to their failure.

Additional work is required to determine the cost-effectiveness of geosynthetics to mitigate ARD/ML.