Lining of mine residue storage facilities

Mike Sadlier
Geosynthetic Consultants, Australia

Fred Gassner
Golder Associates, Australia

John Cowland
GeoSystems Ltd, Hong Kong

ABSTRACT: The lining systems used for mine residue (or tailings) storage facilities are not dissimilar to those used for single lined solid waste landfills, although there are currently less regulations driving the specific liner materials used. The logistics of installing lining systems in storage facilities in remote mining locations means that forward planning is required and extra care is needed to avoid damage to the liner due to climatic effects, such as wind and rain. The QA/QC practices are similar to those used for solid waste landfills. In addition, there is the challenge of keeping material and installation costs to a minimum in line with mining practices. This paper discusses a number of experiences of lining large mine residue storage facilities, especially under tropical conditions, and presents considerations for future lining of mine residue storage facilities.

Keywords: mine residue, tailings, geomembrane liner, case history, lessons learned

1 INTRODUCTION

Mining operations and processing often result in waste streams that contain both solid and liquid components that are often handled as a sludge or slurry and placed in low permeability containment facilities. The solid component sometimes has some residual value that might lead to reprocessing in the future. This residual value, along with environmental concerns, will often lead to a choice of a geomembrane liner for the tailings storage facility.

Once the tailings are placed in storage the solid component tends to settle out leaving a decant liquid, which is often allowed to evaporate or is pumped off and treated as required to allow its reuse or discharge to a stream.

Since tailings ponds tend to take a long time to fill, the geomembrane liners used in tailings facilities face some harsh conditions which include:

- Prolonged UV exposure.
- Exposure to strong winds above the level of solids or water in the pond to provide ballast.
- Exposure to chemical and other elements in the waste stream or in the natural environment.
- Exposure to long term thermal expansion and contraction that can result in ‘thermal creep’ with thinning of the geomembrane at the crest.
- Exposure to drag on the liner as the tailings consolidate, dry and shrink.

Figure 1 A large tailings dam in the tropics with a geomembrane liner where many issues associated with wind and stormwater were addressed.

Figure 2 A lined upstream face of an embankment of a tailings dam with sand filled ballast tubes suspended on the slope

Figure 3 A lined tailings dam where the tailings have dried and settled leading to down-drag on the liner

A large lined residue storage facility was recently constructed on a Pacific island located within a cyclone prone area, which is subject to an annual rainfall average of 4 m per year, varying up to 6 m per year, and wind speeds regularly in excess of 120 km/hour. The Authors were involved in the quality control aspects of the liner installation, which led them to make the following observations for the lining of future mine residue storage facilities.

2 A TYPICAL RESIDUE STORAGE FACILITY

A residue storage facility, constructed in an existing valley, is up to 60 m deep, and includes a zoned soil and rockfill embankment across the valley to retain the stored residue. The approximately 1 km long embankment has a clayey upstream core, a filter curtain and a rockfill downstream zone. The design was prepared to include a lined storage basin in response to ground conditions at the site.

2.1 *The lining system*

The storage basin liner comprised a clayey silt subgrade overlain by a 1.5 mm thick linear low density polyethylene (LLDPE) geomembrane. The embankment was lined with a 2 mm thick LLDPE geomembrane liner generally placed on a slope of 2H in 1V. The embankment includes a number of intermediate benches, nominally at a 10 m vertical spacing, to facilitate the staged construction of the geomembrane liner on the slope. The total lined area of approximately 1.3 million m2 was installed in stages to suit the earthworks construction of the embankment and preparation of the side slopes of the storage.

The figure below shows the initial stage of the works, with the embankment on the right and the basin in the middle, with the first stage of geomembrane liner on the floor of the basin.

Figure 4. Early stage of construction.

2.1.1 *Site formation*

The existing geometry of the storage comprised steep slopes around the entire perimeter of around 3H in 1V to sub-vertical, depending on the existing ground conditions. These steep slopes were shaped with fill material to flatten the slopes to around 2.5 H in 1 V to help facilitate the lining works and the installation of sub-soil drainage features, underneath the liner, which were required to manage periodic high groundwater levels and flows.

The use of the available silt rich and erodible saprolite soils often found in tropical areas as fill material presented particular challenges during construction. The characteristics of these soils and the high rainfall and wind conditions of the site resulted in limited and often short periods that were suitable for the preparation of the subgrade, and placement and welding of the geomembrane liner.

2.1.2 *Prevention of weather damage during liner installation*

Experience during the early stages of the works resulted in the development of a pre-cyclone inspection and checklist that was implemented just before the start of the cyclone season to confirm the geomembrane liner was “locked–down” to the extent possible to minimise the risk of stormwater runoff or wind entering under exposed edges of the liner, and ballasting of the liner was completed. This system was effective in minimising damage that could result from the severe wind and rainfall conditions experienced during the cyclone seasons.

2.1.3 *Wind ballast*

Due to the high expected wind speeds from passing cyclones, a regular ballast system was installed to hold the liner in place until it was covered by the mine residue. The local soils were utilized for ballast, and these materials were fully enveloped in erosion resistant materials to reduce the loss of material (and hence ballast load) during severe rainfall events. The white strips in Figure 5 along the slope toe are soil ballast mounds fully wrapped in thick geotextile. Some of the geotextile that was exposed to the weather for extended periods showed significant degradation. During the later stages of the works, the ballast was wrapped in thin geomembrane to provide increased durability against ultra violet degradation of the ballast wrapping within the storage. The high design wind velocity at the site required a large amount of ballast to manage the load from wind uplift on the liner.

Figure 5. Ballast along slope toe. Storm Water Drainage

With the high annual rainfall at this mine site and the intense daily rainfall that occurred during storms, it was found that a storm water drainage system was essential to prevent storm water damage to the installed liner and also to allow liner installation to commence quickly after the cessation of rain. Substantial storm water drainage trenches were required to conduct the storm water around the outside of the liner area. Some of these trenches were themselves lined with a geomembrane, and temporary trenches were relocated upslope ahead of the storage slopes shaping earthworks and liner installation.

It is common to install storm water drainage systems around the outside of lined areas in solid waste landfills to prevent clean rainwater from mixing with the landfill leachate and increasing the volume of contaminated water. Similarly, storm water drainage systems are required to prevent rainwater from flowing into the storage of the mine residue and decreasing the remaining available space in a residue storage facility. This is particularly the case in tropical rainstorm areas. Generally environmental control requirements prohibit the discharge of water from a residue storage facility unless it can be shown that the liquid poses low risk to the environment.

2.1.3 *Liner Installation Quality Control*

Liner installation quality control for a mine residue storage facility liner is similar to that used for a solid waste landfill liner. For a remote mine site, forward planning is required for staff rotation on and off the site to keep staff morale high, which helps with high standards of quality control.

It is quite common for a residue storage facility to be commissioned for tailings deposition while the perimeter embankment and liner works are still in progress and often have further campaigns of raising the embankment and liner as the facility fills. This presents challenges to coordinate the on-going earthworks and lining works with the related controls to minimize damage and completing construction quality assurance processes. Interfacing between ongoing earthworks and liner installation requires detailed planning and controls to manage the risks associated with rainfall runoff and wind entering below completed liner portions.

Spill-over of soil and rock from earthworks onto completed liner areas also poses a high damage risk to the liner from scratches and puncture from sharp hard particles. Saprolites often include hard particles from less weathered pockets in the soil profile and cementing effects related to the weather conditions in the tropics.

2.1.4 *Control of liner exposure*

On some sites the residue or tailings is pumped into these facilities as a warm slurry. The slurry often comprises rock flour and crushed particles with high abrasion potential. These features can be damaging as it impacts on the liner. Sometimes an additional layer of geomembrane or rock erosion protection layer is used as protection of the liner or a modified inlet pipe is used so that the incoming slurry does not impact on the liner.

Figure 6. A pipe discharging hot slurry directly on to a liner

Figure 7. HDPE pipes with floats so that discharge is away from liner. These pipes are shown entering the facility beneath a cover, and the floating exits of the pipes are well above the liner.

2.2 *Completed Residue Storage Facility*

The lining of the residue storage facility was completed in December 2016, and Figure 8 shows the storage facility at that time. The level of stored liquid shown in the figure is about 20 m below the crest of the containment embankment.

Figure 8. Completed residue storage facility.

3. RECOMMENDATIONS

From our experiences on a number of difficult mine sites, we have the following recommendations.

- Considerable thought should be given to purchasing the most appropriate liner for the site conditions to ensure a robust outcome. The temptation to purchase the lowest cost liner can result in higher site formation costs and once repairs and replacements are implemented of a low durability liner.
- Subgrade preparation and shaping should be designed to enable liner installation works. Difficult liner installation results in a higher risk of lower quality installation.
- To maintain the integrity of the installed liner until it is covered by the mine residue, it is necessary to give design thought to the short to medium term wind ballasting system. In high wind sites the ballasting of the liner should also consider the progressive installation process of the lining system.
- It is also necessary to design and install a suitable storm water drainage system to direct storm water around the outside of the lined area, and to ensure that the storm water drainage system is able cope with peak rainfall conditions. Heavy rainfall events can result in damage to the liner and substantial consumption of the residue storage volume until the stormwater is removed. This is likely to impact on embankment and liner raise staging of the works.
- The residue discharge system should be designed in consort with the liner design to reduce the risk of damage to the system during operation. This requires coordination with the operations staff.
- The lining system needs to consider the effects of drag down loads on the liner when the residue settles due to consolidation and drying.

REFERENCES

Giroud, J.P., Pelte, J. and Bathurst, R. J. 1995b. Uplift of Geomembranes by Wind, Geosynthetics International 1995, Vol.2, No. 6, pp. 897-952