Leach pad design and construction issues in very steep slopes

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ABSTRACT: This paper presents the successful experience of Vector with the design and construction aspects of leach pads in very steep slopes. With regards to design considerations, the following issues are discussed: heap stability, intermediate benches, geomembrane liner, soil liner or GCL, overliner placement, among others. With regards to construction of these facilities with very steep slopes, this paper describes experience with: placement and compaction of soil liner on slopes, compaction control on slopes, temporary and permanent anchoring of the geomembrane, deployment of GCL on long slopes, placement of drainage gravel at mid-slope locations, inspection of the geomembrane, safety concerns for personnel and equipment, climate concerns (wind, rain), among others.

1 BACKGROUND

Leach pads are facilities that are designed and constructed for the recovery of metals through leaching, and they use geosynthetics to protect the environment and collect the pregnant solution.

The conditions imposed by steep slopes, mainly in valley fill leach pad design, submit the geosynthetic elements used in these facilities to their limits of behavior. These extreme conditions and limits must be considered during the design and construction phases, since the geosynthetics make up one of the most important parts of these facilities.

2 DESIGN ISSUES ON VERY STEEP SLOPE LEACH PADS

The most relevant aspects regarding the leach pad design with very steep slopes are described below.

2.1 *Heap leach pad stability*

The global stability of a leach pad, mainly in a valley fill type, is controlled through a stability platform or a stability berm, located at the toe of the heap. The width of the platform or the size of the berm must meet the static and seismic stability criteria for the ultimate heap configuration. For a leach pad with steep slopes, the stability is not really a concern since the failure surface will develop through the uphill direction. Therefore, the steeper slope, the greater the factor of safety obtained in the stability analysis.

2.2 *Intermediate benches*

Intermediate bench construction has been part of the leach pad facility design success over the years in dealing with very steep slopes. Figure 1 shows the intermediate benches on a steep slope leach pad. The following aspects should be considered as part of the design process;

- Geomembrane roll length commercially available for the selected thickness. In these particular cases, it is preferred to use a liner thickness of no less than 2mm, for which roll lengths of about 120m are available. It is possible to request “special” rolls, but usually no longer than about 150m, due to requirements handling the heavier rolls.
- Rainfall water management. The bench configuration allows the deviation of rainfall water along the benches, preventing runoff from entering the collection system and also avoiding the dilution of pregnant solution in the lower areas of the pad.
- Zonation of the solution collection. The solution can be collected by zones equivalent to the area between benches or smaller areas, allowing for the recirculation of low grade solution.

The slopes between benches depend on the natural terrain configuration. Although less than 2H:1V (27 degrees) is advisable, or even less than 2.5H:1V (22 degrees), due to construction issues and safety considerations, mining project scan be located for instance in high Andean zones (Peru, Colombia), where the terrain configuration pushes for the need to use slopes greater than 2.5H:1V (34 degrees), such as that shown in Figure 2, and even near vertical in the cut of the benches, as shown in Figure 3.

Figure 1: Intermediate benches in steep slopes geomembrane lined leach pad.

Figure 2: Very steep slope for a leach pad.

Figure 3: Near vertical cut slope.

2.3 *Geomembrane liner*

In general, single side textured geomembrane is advisable to be used in a leach pad, with the texture side in contact with the soil liner and the smooth side in contact with the ore or overliner. The objective is to increase the weakest interface strength, usually that of the soil liner-geomembrane, avoiding the rupture of the liner due to any ore movement during ore stacking operations in the heap. The steep slope increases the ore movement as well as the shear stresses in the geomembrane, requiring even more so, to have the smooth side to be in contact with the ore or overliner.

Currently LLDPE geomembrane is a preferred liner for leach pads due to improved elongation and frictional resistance in comparison to HDPE, which improves puncture resistance and interface shear strength.

2.4 *Soil liner vs GCL*

One of the main concerns related to very steep slopes is soil liner placement, which becomes a very complicated process. In general, according to the successful experience in design with very steep slope conditions, one of the following recommendations can be followed:

- For slopes less than 1.5H:1V, soil liner can be used, with safety cautions during compaction.
- For slopes greater than 1.5H:1V, the use of GCL is recommended.

The utilization of GCL is more expensive than the soil liner; however, its placement is much safer when the slope is very steep, requiring only small anchor trenches at the upper part of the slope. Also, in rocky slopes, such as that shown in Figure 3, it is necessary to protect the GCL to prevent damage from the sharp edges of the rocky outcrop. This protection can consist of a geocomposite (geotextile-geonet-geotextile), which will additionally provide a drainage layer for any groundwater springs on the slope.

2.5 *Overliner*

The placement of overliner is not possible on slopes greater than 2H:1H. Overliner needs to be placed as the heap is raised, filling the space between the operating lift and the steep slope. The stacking of the current lift must be strictly controlled to avoid segregation of large particles which can damage the liner, resulting in additional efforts and costs to the project.

3 CONSTRUCTION OF VERY STEEP SLOPE LEACH PADS

With regards to construction of these facilities with very steep slopes, a description is presented of the most relevant aspects of our experience.

3.1 *Placement and compaction of soil liner*

Normally soil liner on slopes is placed by dumping the material at the toe of the slope and spreading the material with bulldozers, pushing the material uphill. However, placement of the soil liner on steeps slopes with intermediate benches defined by near vertical cut slopes, makes this method impossible. Soil liner material must be dumped at the top of the slope and pushed downhill, sometimes for long distances. This can cause problems with rolling rocks, which requires safety precautions for personnel and installed geomembrane downhill from the placement operation. Placement of moveable, temporary barricades at the bottom of the slope or on an intermediate bench to stop rolling material is essential. It is important that no personnel or equipment be permitted to be working downhill of this operation.

Equipment and procedures for the compaction of the soil liner must be well defined as part of the contractor bidding process, including all safety precautions. Compaction of soil liner on steep slopes requires that the smooth drum rollers are connected by steel cables to either a winch on a bulldozer or a pulley system connected to heavy equipment, as shown in Figure 4. These special equipment requirements must be planned for by the earthworks contractor and can add significant but necessary additional costs to the project. Safety measures must include the removal of all personnel and equipment downhill of this operation due to the increased risks.

Figure 4: Compaction in a very steep slope.

3.2 *Compaction control*

Due to the inherent difficulties of material placement on steep slopes, proper soil liner thickness must be verified through the use of small test pits. Quality control (QC) and quality assurance (QA) personnel must be prepared to walk long distances with all the necessary equipment for performing nuclear density gauge (preferred) and sand cone tests. Sand cone tests require the excavation of a horizontal platform on the slope, resulting in longer testing times. The authors have had some success correlating density gauge data with sand cone test results performed directly on the slope (variation of the ASTM procedure) by first calibrating the sand cone on a simulated slope similar to that in the leach pad.

3.3 *Placement and inspection of geomembrane*

Geomembrane installations on steep slopes in areas with heavy rainfall/high winds require diligence in the face of these threats. On steep slope leach pads, the control of surface rainwater is critical to avoiding damage to prepared soil liner down gradient of the discharge point. Control measures for can include temporarily anchoring the liner in shallow trenches on the up gradient end of the leach pad, placement of rub sheets at the discharge point, and channeling the runoff as it leaves a lined area to an area beyond the prepared subgrade.

As with any project, ballast to prevent uplift of the liner is a requirement. On steep slopes however, sand bags must necessarily be tied off on rope lines in order to prevent them from sliding out of place. Movement of these sandbag lines as liner installment progresses will usually require the use of equipment and extra personal in order pull the entire ballast line to its new position. Care must be taken to ensure that the sand bag fill material does not damage the geomembrane when they are dragged across the liner.

The combination of steep slopes and wind can also cause problems with liner uplift. Increased ballast/installation of air vents (appropriately protected from the rain with a patch welded on 3 sides) can help reduce the pillowing effect of winds (see Figure 5). If air vents are used, care must be taken to ensure that the vents are properly sealed if/when they will be covered with ore material.

Figure 5: Placement of heavy ballast on installed geomembrane to prevent uplift.

Wrinkle distribution for geomembrane on very steep slopes is very different from normal installations. Instead of small wrinkles even distributed along the length of the panel, gravity tends to cause one large wrinkle (> 1 meter) to form at the toe of the slope. Welding the tie in correctly to avoid trampolining is very important. Placement of overliner/ore when the liner is at its coldest (i.e. no wrinkles) must be carefully monitored

Walking on steep slopes that are lined becomes an issue for both the installer and the inspectors. Facilitating the movement of the welding technicians becomes important, especially for the fusion welder operators. Each operator must be provided with a way of walking on the slope without losing control of the equipment. This can be achieved through the use of cat ladders, knotted ropes, or by the operating using a harness attached to a rope with an assistant at the top of the slope to control their ascent/descent.

Individuals such as QC/QA personnel walking on the liner also need to use harnesses attached to safety lines that allow for their movement on the liner. This can include a safety line attached to a stake at the top of the slope, or the use of an assistant that can provide them with a greater range of movement.

3.4 *Temporary and permanent anchoring of geomembrane*

Anchoring deployed geomembrane in areas with very steep slopes is a critical issue. Extra weight must be placed in the anchor trench due to additional down forces present from the weight of the geomembrane. Unwelded geomembrane panels can easily slide out of the anchor trench and roll downhill causing severe injuries or even death to personnel working downhill of the anchor trench. Immediately welding newly deployed panels to previously deployed panels becomes a priority for the installer in order to reduce this danger. Permanent backfill and compaction of the anchor trench needs to be performed as soon as possible to avoid any movement of the geomembrane downhill.

3.5 *Placement of trench backfill at mid-slope locations*

Placement of drainage gravel or trench fill at mid-slope locations is difficult due to limited access by heavy equipment. Temporary chutes made of large diameter dual wall HDPE pipe can speed up the placement of the material in areas where equipment can't reach, as shown in Figure 5. If need be, the pipe can be cut in half along the length of the pipe in order to provide an open chute where the material can easily be pushed further down slope with a shovel. If the trench is near the top of a cut slope, the use of a small crane with a concrete bucket can facilitate the transport of the material to the trench location.

3.6 *Deployment of GCL on long slopes*

Placement of GCL on very steep slopes also requires a reconsideration of normal installation practices. For the placement of GCL in a mid-slope position, precutting the panels to size, rolling up each individual panel and positioning it by hand or by crane has been necessary but successful alternative. Again, care must be taken to ensure that the GCL panels don't lose their anchoring and roll down the slope, potentially injuring construction personnel.

Figure 5: Dual wall HDPE pipe used as a chute.

4 CONCLUSION

Design and construction of a heap leach pad is very steep slope terrain is a challenge. Design issues are related to: intermediate benches based on roll length, rainfall water management and efficient solution recovery; geomembrane liner design to prevent damage due to the ore movement during the stacking operation; use of soil liner or GCL depending if the slope is 1.5H:1V or steeper; and overliner placement which is not possible in slopes greater than 2H:1H. Construction issues are related to: placement and compaction of soil liner, which requires that the rollers are connected by steel cables to either a winch on a bulldozer or a pulley system connected to heavy equipment; soil liner compaction control on slopes; placement and inspection of geomembrane, with temporary and permanent anchoring, channeling the runoff, ballast placement to prevent uplift by wind and verifying the wrinkle distribution which is very different from normal installations; and deployment of GCL on long slopes.

REFERENCES

Breitenbach, A. J. 2004. Improvement in slope stability performance of lined heap leach pads from operation to closure. *Geotechnical Fabrics Report*, v. 22, no. 1, pp. 18-25.

Breitenbach, A. J. & Smith, M.E. 2007. Overview of geomembrane history in the mining industry. *Mining Record.*

Lupo, J.F. 2008. Steep terrain heap leach pad liner system design. *The First Pan American Geosynthetics Conference & Exhibition*, pp. 1546-1555.

Smith, M.E. 2002. Potential problems in copper dump leaching. *Mining Magazine*.

Thiel, R., and Smith, M.E. 2004. State of the practice review of heap leach pad design issues. *Geotextiles and Geomembranes*, 22(6): 555-568.