

Evaluation and quality control of geosynthetic clay liners in heap leach pads

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Abstract

The design of heap leach pads has become more challenging over the years, in the quest for efficient solutions that will guarantee the constructability, quality, and economic feasibility of such projects. The solutions are usually focused on activities related to earthworks that consume up to 70% of heap leach projects' capital cost.

A critical factor for a heap leach project is that the soil liner or low-permeability soil needs to be in contact with a geomembrane as a composite heap liner. One of the alternatives is to replace such soil material—when it is unavailable or unsuitable—with a geosynthetic clay liner (GCL), which is a prefabricated geocomposite made of bentonite, or another kind of very low-permeability material, that is encapsulated by two geotextiles layers, which may be mechanically joined by a needle-punching process, stapling, or using adhesive chemicals. The engineering function of a GCL is the formation of a second hydraulic barrier, with the first one being the geomembrane sheet. This approach is used mainly on steep slopes, usually greater than 2H:1V, where the use of earthworks equipment is impractical, unsafe, and expensive for placing and compacting a soil liner.

This paper presents a discussion of the advantages and disadvantages of the use and applications of GCL compared to low-permeability soil in different heap leach pad projects in Peru and other countries where very steep slopes and aggressive terrains are found. It also discusses the positive aspects of GCLs, primarily in terms of cost and time savings. Design considerations for optimizing the use and hydraulic and mechanical behavior of GCL installations are also discussed.

Introduction

The use of a GCL as a replacement for low-permeability soil in the construction of heap leach pads is increasing for several reasons, including: limited availability of low-permeability soil borrow areas near the

project location, earthworks optimization, alternative for soil liner in steep slopes, optimization of construction time. However, the use of this material requires taking into account several considerations during design and installation, such as: identifying areas where a GCL can be placed without compromising the stability of the heap leach pad because of the very low shear strength of the GCL and geomembrane interface; using intermediate benches because the GCL roll's length is always much shorter than that of the geomembrane roll; overlap design for preventing GCL edge separation; and good quality control during installation.

Considerations for using GCL

The choice on whether or not to use a GCL as a second impermeable barrier in a heap leach pad must be based on the specific characteristics of the project. The location, distance to soil liner borrow source, available quantity and quality of soil liner, and environmental conditions are relevant aspects that must determine whether the use of a GCL is the best alternative for the project. Below, the most important aspects to be considered in GCL selection are described.

In slopes steeper than 2H:1V, the placement of conventional soil liner becomes difficult and takes a long time, and rigorous safety precautions must be taken. In some projects safety restrictions preclude pulling a roller with wire for soil liner compaction on steep slopes; therefore, only a GCL can be placed as a substitute for a conventional soil liner.

The distance from the project to the low-permeability soil borrow source and the availability of enough of this material, plus the cost of hauling the material to the site, must be evaluated and be compared with the cost of using a GCL. Additionally, the moisture content of the soil liner at the borrow source is also important, particularly if construction will be done during rain events or the rainy season.

In many cases, construction time is quicker using a GCL, because surface preparation and GCL placement is much faster than the surface preparation, grading, placement, and compaction of low-permeability soil. However, it is important to note that in some cases when rocky outcrops are being graded by blasting, the extreme irregularities may damage the GCL and the geomembrane; in such cases the surface must be smoothed by using shotcrete or mortar (see Figure 1), or by placing sandbags, or in some cases by using electrowelded wire mesh.

In Table 1, a comparison between GCL and conventional clay liner installation is listed (modified from Cesar et al., 2013).

Table 1: Soil liner and GCL comparison

Compacted soil liner	Geosynthetic clay liner
Generally the most economical alternative as long as the slope is less than 2.5H:1V or even 2H:1V, and proper borrow sources are available close to the site.	More economical on irregular slopes after blasting, and when soil liner is not available close to the site.
Can be used on slopes up to 1.5H:1V. Restricted in some places to 2H:1V or 2.5H:1V.	Can be used on any slope of a leach pad with the previous verification of overall geotechnical stability.
Can be placed directly on subgrade and structural fill, according to the grading design.	In steep, rocky slopes with irregular shapes, must be placed in conjunction with geocomposite or geotextile to avoid punctures.
Can be placed on very irregularly shaped subgrades.	Because of the roll length, intermediate benches have to be designed and constructed for anchoring.
Does not require intermediate benches, unless the solution collection system needs them.	Vulnerable to hydration by phreatic level in foundation, decreasing its efficiency as protection.

Considerations, procedures, and installation of GCL

The use of GCL as a second impermeable barrier requires some considerations for proper installation, performance, and protection.

Anchoring

Benches are needed for GCL anchorage in an anchor trench, which attaches the GCL to the subgrade, providing resistance against pullout and avoiding seams between GCL panels on steep slopes. The location and configuration of the benches are based on the maximum length of the GCL rolls, which is typically 45 m, although some manufacturers provide 75 m roll lengths. Figure 2 shows a typical bench where a GCL is anchored into a trench filled with compacted low-permeability soil.

The benches provide some advantages, such as:

- They can be used as a phase border or phase division in a construction, because they provide an independent solution-collection system, making solution recovery more efficient.
- They allow the control of the rainwater upstream of the bench by collecting and evacuating the flows along the bench.



Figure 1: Surface preparation before GCL and geomembrane installation

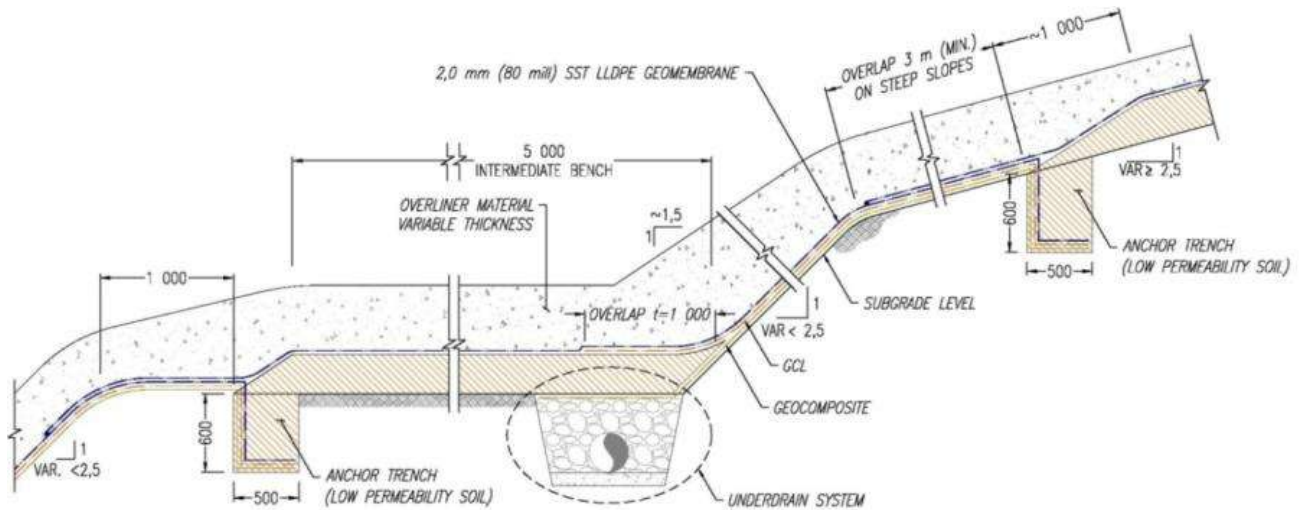


Figure 2: Typical intermediate benches in a leach pad

Protection

Cost should be taken into account when adding layers to prevent damage to the GCL (tearing) from nonuniform and aggressive surfaces like rocky outcrops as result of blasting. This cost must be assessed in order to obtain an accurate final budget for the implementation of GCL in the project; then it should be compared with the cost of using a conventional soil liner.



Figure 3: Surface prepared before GCL and geomembrane installation

Mortar

Sometimes a thin layer of mortar (sand plus cement) is needed in order to provide a uniform surface (see Figure 3).

Geotextile

A heavy geotextile such as 500 g/m² can be used for protection in order to prevent puncture and tears in the GCL.

Geocomposites

The use of geocomposite is necessary in nonuniform slopes, where sharp rock fractures can damage the GCL or even the geomembrane. Geocomposites have often been used in heap leach projects in Peru. As an additional advantage, the geocomposite can collect any underground water not collected by the underdrain system, avoiding hydration of the GCL, as shown in Figure 4.

Wire mesh

In more aggressive slopes or rocky terrain with sharp rock faces because of blasting, such as the slope shown in Figure 5, electrowelded wire mesh is placed in contact with the rock, then the geocomposite is placed, followed by the GCL. The figure 6 shows the surface where a mesh will be placed to obtain a smoother surface before the placement of a geocomposite and subsequently a GCL.



Figure 4: Geocomposite, GCL, and geomembrane installation



Figure 5: Protection must be included in sharp slopes in order to avoid damage to the GCL



Figure 6: Surface where a mesh will be placed

Geotechnical design

When a GCL is used instead of a soil liner, the shear strength of the GCL-geomembrane interface is much lower than the soil liner-geomembrane one; therefore, heap leach pad stability needs to be addressed. A large-scale direct shear test is usually performed to determine the shear strength of this interface, which includes hydration due to solution leakage through the liner system or from underground water.

Cesar et al. (2013) note that GCL must not be used in platforms or lower zones in the leach pad in order to avoid stability problems; thus low-permeability soil liners have to be used in those circumstances.

QA procedures for GCL installation

Observation and testing procedures required for the installation of GCL are described in this section. In order to monitor installation, a construction quality assurance (CQA) manual must be compiled and followed; this should include material conformance testing and construction observation. Conformance testing refers to activities that can be performed prior to installation. Construction testing includes activities that are performed during installation.

A CQA engineer should observe all of the installation activities at the site. It is the responsibility of the CQA engineer to ensure the monitoring required and specified in the CQA manual, such as:

- Before the GCL manufacturing, suppliers should be informed of the quality requirements indicated in the technical specifications of the project.

- Prior to the GCL shipment, suppliers should deliver to the owner and CQA engineer the relevant certificates of manufacturing quality assurance (MQA) for review.
- Before receiving the GCL on site, the CQA engineer should review the quality certificates issued by the manufacturer in order to verify conformance with the technical specifications of the project.
- When the GCL is admitted on site, the CQA engineer should verify the status of the GCL rolls, as well as ensuring their proper storage.
- The CQC engineer and the installer should coordinate regarding the procedure of GCL installation, checking recommendations from the manufacturer and reviewing the technical specifications and the CQA manual.
- The CQA engineer must inspect the GCL installation and ensure there is procedure conformance.

Conformance testing

The CQA engineer should take samples according to the requirements of the CQA manual at a frequency of one test per 10,000 m². All conformance tests should be done with the appropriate methods and following the recommended standards.

Unless the CQA engineer determines otherwise, the GCL samples should be tested in an external, qualified laboratory in order to check the following properties:

- Mass per unit area, to verify that the GCL roll retains at least 95% of the original bentonite that was used in the factory (with a 0% of moisture content).
- The hydraulic conductivity should be tested in accordance with ASTM D-5048.
- The strength and elongation should be tested in accordance with ASTM D-4632.

Any roll that does not meet the minimum properties indicated in the technical specifications should be rejected, unless the CQA engineer authorizes otherwise.

Any material that is not certified in accordance with the technical specifications of the project, or that has a higher hydraulic conductivity than that described therein, should be rejected and replaced with new material by the supplier.

GCL installation

The GCL should be installed in the areas shown in the drawings of the project. Before GCL installation, the surface should be as smooth as possible, free of obstructions, depressions, and sharp objects. As previously indicated, protection must be placed if needed. The GCL should be deployed with the long dimension on the slope and should be extended in order to obtain a smooth surface, free of tension, stress, folds, or wrinkles.

At the top of the slopes, the GCL will be attached to an anchor trench and then deployed downslope. Then a manual relocation must be done, if necessary, to minimize wrinkles and folds. Also, during the placement of an underlying protection layer (geotextile, geocomposite, or wire mesh), the installer has the responsibility to verify that the protection layer is not obstructed and that no stones are present that could damage the geomembrane or GCL.

GCL repairation

All holes or tears in the GCL should be repaired with a patch (using the same grade of GCL), which should extend 300 mm beyond the edges of the hole or tear; this must have a chamfer of granular bentonite or another seal material (free of foreign materials such as needles), accepted by the CQA engineer. No nails or staples should be used to secure the patch.

The owner should give his approval when the CQA engineer finishes all of the CQA tasks, all defects have been repaired, and all documentation from the manufacturer, supplier, installer, and laboratory has been received and accepted.

One of the main problems encountered after GCL installation is the shrinkage of the GCL panels, causing separation between the GCL panels; therefore, there should always be a minimum overlap of between 150 and 400 mm, depending on the slope, the weather conditions, and the recommendations of the manufacturer. However, GCL contraction depends on climate changes, not on surface slope.

Figure 7 shows a contraction in the GCL after being placed that led to the separation of the panels because of insufficient overlap. Radical changes in temperature between day and night were likely the reason for contraction and later separation. In areas where large temperature variations are expected, the minimum overlap should be 300 mm in slopes less than 1H:1V, meanwhile it should be 500 mm as minimum in slopes greater than 1H:1V due to the slenderness generated in the body of the strip because of the weight thereof.

Case histories of GCL usage

Observation and testing procedures required for the GCL installation are described in this section by presenting two case studies.

Case 1: Optimizing earthworks

This heap leach pad project of 89.9 ha, located in southern Peru, will be built in a narrow valley, where the slopes average 1.5H:1V. The earthworks projected, mainly cutting, in order to reach the subgrade surface, were about 830,000 m³, of which 30% was cut from solid rock. Of the 89.9 ha of the leach pad, 35.7 ha corresponds to areas where the slopes were steeper than 2.5H:1V, which represents 39% of the area. For

the conventional placement of low-permeability soil liner, an additional cut would be necessary for grading the surface lower than 2.5H:1V; this would require a volume of 1,840,000 m³, which would be 221% of the original cut. The zones where additional cuts were needed are shown in Figure 8 in green, with a typical section shown in Figure 9. However, all of these additional earthworks were avoided through the use of GCL in slopes steeper than 2.5H:1V.



Figure 7: GCL contraction and panel separation due to insufficient overlap

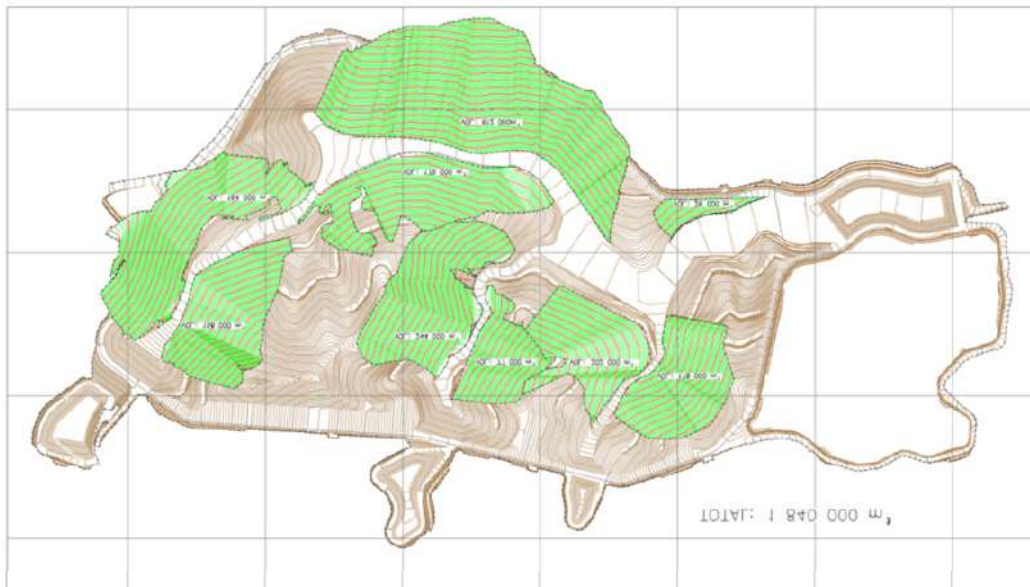


Figure 8: Zones where additional cut is needed for reducing steep slopes

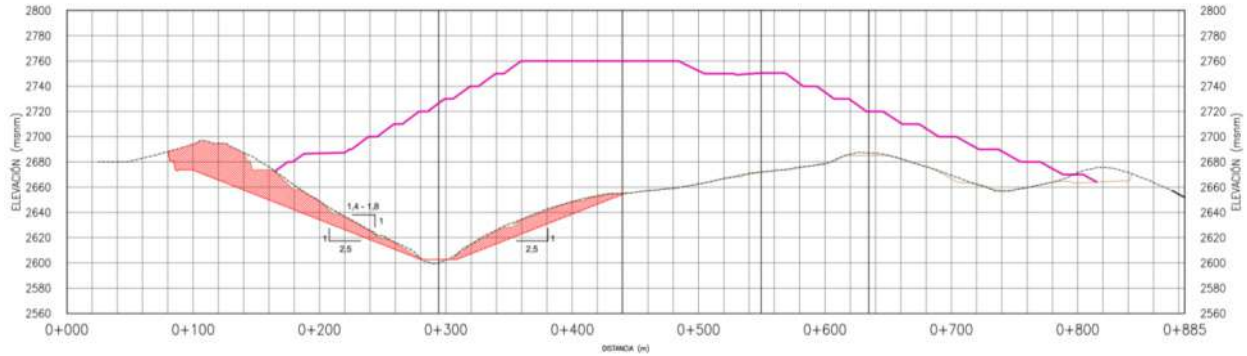


Figure 9: Typical section showing the additional cut, which finally was avoided by using GCL

Case 2: Availability of low-permeability soil

This particular case is a situation where there is limited availability of optimal material that could be used as a low-permeability soil liner and a lack of borrow sources where this material could be obtained. In this case it was necessary to place as much GCL as possible without compromising the stability of the leach pad.

One of the main problems arising in this case is that it could generate a large volume of earthworks in order to improve stability. Also, in rainy environments and especially on flat areas, care must be taken to avoid the hydration of the GCL; even moderate rainfall could cause deterioration.

Figure 10 shows a typical project drawing for a region in northern Peru (rainy region) where soil liner availability is restricted mainly because of moisture content issues; the design criteria for installing GCL includes some areas of the leach pad where the slopes are lower than 2.5H:1V.

Conclusions

The conclusions and recommendations drawn from this evaluation are the following:

- When low-permeability soil liner is not available near the project or is limited because of high costs for obtaining or preparing this material, it is important to perform a comparative cost analysis with GCL usage.
- The GCL should be protected from punctures by nonuniform or sharp-edged surfaces, by using mortar, geotextiles, geocomposites, wire mesh, or another system.
- The use of a GCL is an option for heap leach pad projects in very aggressive terrain; earthworks optimization should be performed to reduce the overall cost of the project.

- A CQA engineer should monitor every step of the process and take samples as required for testing, following the project's CQA manual.

References

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