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GEOSYNTHETIC CLAY LINERS USED IN MUNICIPAL SOLID WASTE LANDFILLS

This fact sheet describes new and innovative technologies and products that meet the performance standards of the Criteria for Municipal Solid Waste Landfills (40 CFR Part 258).

Geosynthetic clay liners (GCLs) represent a relatively new technology (developed in 1986) currently gaining acceptance as a barrier system in municipal solid waste landfill applications. Federal and some state regulations specify design standards for bottom liners and final covers. Alternative technologies are allowed, however, if they meet federal performance standards. GCL technology is an alternative that performs at or above standard federal performance levels.

GCL technology offers some unique advantages over conventional bottom liners and covers. GCLs, for example, are fast and easy to install, have low hydraulic conductivity (i.e., low permeability), and have the ability to self-repair any rips or holes caused by the swelling properties of the bentonite from which they are made. GCLs are cost-effective in regions where clay is not readily available. A GCL liner system is not as thick as a liner system involving the use of compacted clay, enabling engineers to construct landfills that maximize capacity while protecting area ground water.

Before using a GCL in a landfill barrier system, remember there currently are no standard methods for comparing GCL products or installation systems. In addition, GCL performance properties, including the ability of GCL liner systems to effectively prevent landfill leaching, have not yet been firmly established.

This emerging technology is currently in use at a number of sites across the nation. This fact sheet provides information on this technology and presents case studies of successful applications.

GCL TECHNOLOGY

Materials

A GCL is a relatively thin layer of processed clay (typically bentonite) either bonded to a geomembrane or fixed between two sheets of geotextile. A geomembrane is a polymeric sheet material that is impervious to liquid as long as it maintains its integrity. A geotextile is a woven or nonwoven sheet material less impervious to liquid than a geomembrane, but more resistant to penetration damage. Both types of GCLs are illustrated in Figure 1. (To view Figure 1, see PDF version ofthis document.) Although the overall configuration of the GCL affects its performance characteristics, the primary performance factors are clay quality, amount of clay used per unit area, and uniformity.

Bentonite is an extremely absorbent, granular clay formed from volcanic ash. Bentonite attracts positively charged water particles; thus, it rapidly hydrates when exposed to liquid, such as water or leachate. As the clay hydrates it swells, giving it the ability to "self-heal" holes in the GCL. In laboratory tests on bentonite, researchers demonstrated that a hole up to 75 millimeters in diameter will seal itself, allowing the GCL to retain the properties that make it an effective barrier system.

Bentonite is affixed to synthetic materials in a number of ways to form the GCL system. In configurations using a geomembrane, the clay is affixed using an adhesive. In geotextile configurations, however, adhesives, stitchbonding, needlepunching, or a combination of the three, are used. Although stitchbonding and needlepunching create small holes in the geotextile, these holes are sealed when the installed

GCL's clay layer hydrates. Figure 2 (To view Figure 2, see PDF version of this document.) shows cross-section views of the three separate approaches to affixing bentonite to a geotextile.

Properties and Characteristics

An important criterion for selecting an effective landfill barrier system is hydraulic conductivity. Before choosing a barrier system, the landfill operator should test the technology under consideration to ensure that its hydraulic conductivity, as well as other characteristics, are appropriate for the particular landfill site.

Hydraulic Conductivity

GCL technology can provide barrier systems with low hydraulic conductivity (i.e., low permeability), which is the rate at which a liquid passes through a material. Laboratory tests demonstrate that the hydraulic conductivity of dry, unconfined bentonite is approximately 1 x 10-6 cm/sec. When saturated, however, the hydraulic conductivity of bentonite typically drops to less than 1 x 10-9 cm/sec.

The quality of the clay used affects a GCL's hydraulic characteristics. Sodium bentonite, a naturally occurring compound in a silicate clay formed from volcanic ash, gives bentonite its distinct properties. Additives are used to enhance the hydraulic properties of clay containing low amounts of sodium bentonite.

Hydraulic performance also relates to the amount of bentonite per unit area and its uniformity. The more bentonite used per unit area, the lower the system's hydraulic conductivity. Although the amount of bentonite per unit area varies with the particular GCL, manufacturers typically use 1 pound per square foot. As a result, the hydraulic conductivity of most GCL products ranges from about 1 x 10-5 cm/sec to less than 1 x 10-12 cm/sec. That is, the permeability of finished GCL products depends on a combination of factors, including the type and amount of bentonite, the amount of additives, the type of geosynthetic material, and the product configuration (i.e., the method of affixing the geosynthetic to the clay).

Shear Strength and Other Characteristics

Depending on the particular configuration of the barrier system, GCL technology can provide considerable shear strength (i.e., the maximum stress a material can withstand without losing structural integrity). In particular, a geotextile-backed GCL, with bentonite affixed via stitchbonding, provides additional internal resistance to shear in the clay layer. Needlepunching yields an even stronger, more rigid barrier. In addition, needlepunching requires the use of a nonwoven geotextile on at least one side. These GCL configurations provide enhanced interface friction resistance to the adjoining layer, an important consideration for landfill slopes.

Both needlepunching and stitchbonding, however, tend to increase the cost of the GCL product. Needle-punching, in particular, adds to a GCL's cost, because nonwoven geotextiles are generally more expensive than woven geotextiles.

Before selecting a final barrier system, landfill operators should consider other important performance characteristics, such as free and confined swelling (i.e., whether the clay will provide a uniform barrier) and rate of creep, which measures the resistance to barrier deformation.

Testing

GCL configurations for barrier systems are based on the design specifications of each specific project. The American Society for Testing and Materials (ASTM) developed standardized laboratory tests for assessing mass per unit area (ASTM D-3776), hydraulic conductivity (ASTM D-5084), and direct shear (ASTM D-5321).

Researchers at the Geosynthetic Research Institute at Drexel University (in Philadelphia, Pennsylvania) and the Geotechnical Engineering Department at the University of Texas (in Austin) developed tests to measure shear strength, as well as confined swelling, rate of creep, and seam overlap permeability. These test methods have been adopted by ASTM. Additionally, the bentonite industry developed a test to measure free swell (USP-NF-XVII).

Test values for hydraulic conductivity depend on the degree of effective overburden stress around the GCL during testing. The higher the effective overburden stress, the lower the hydraulic conductivity. When comparing two different bentonite products, both must be subjected to the same degree of effective overburden stress.

AVAILABLE GCL PRODUCTS

Product Types

The following types of GCL products are currently available:

* Geotextile type:

  -- Bentofix(R) (activated sodium bentonite as primary ingredient and affixed by needlepunching to a woven or nonwoven upper geotextile and a nonwoven lower geotextile).

  -- Bentomat(R) (sodium bentonite as primary ingredient and affixed by needlepunching to a woven or nonwoven upper geo-textile and a nonwoven lower geotextile).

  -- Claymax(R) (sodium bentonite as primary ingredient mixed with water-soluble adhesive and bonded or stitchbonded to a woven upper and lower geotextile).

* Geomembrane type:

  -- Gundseal(R) (sodium bentonite as the primary ingredient mixed with an adhesive and bonded to a blend of high density polyethylene and very low density polyethylene).

Table 1 (To view Table 1, see pdf version of this document.) lists information on variations of these product types by manufacturer, and Figure 3 (To view Figure 3, see pdf version of this document.) presents cross-section views of these product configurations.

In general, manufacturers ship GCL products in rolled sheets ranging from 13 to 18 feet wide and from 100 to 200 feet long. GCLs range in thickness from 0.2 to 0.3 inches.

Installation

Landfill operators can install all available GCL products much faster and more easily than compacted clay liners. Unlike compacted clay liners, however, GCLs are more susceptible to damage during transport and installation. Care should be taken during and after installation to avoid hydration. Hydration results in unconfined swelling of the bentonite and causes the geotextile layers to pull apart, undermining the integrity of the GCL configuration.

Manufacturers usually specify individual GCL installation procedures. Basic procedures, however, call for rolling out the large GCL sheets onto the site subgrade, which should be smooth (e.g., free of stones and grade stakes), well compacted, and dry. Once installers cover the GCL with soil, the GCL hydrates by drawing moisture from the soil. As a result, when laying out the GCL, installers must allow enough seam overlap at adjoining sheets to guard against the potential opening of the barrier system. Currently, the recommended amount of seam overlap and other seaming considerations vary with the particular GCL product. Thus, installers should follow the manufacturer's instructions for the particular product.

GCL manufacturers, and some private engineering firms, provide training for GCL installers. Among other considerations, instructions typically emphasize techniques for minimizing potential damage to the GCL during installation. The National Institute for Certification of Engineering Technologists in Alexandria, Virginia, offers a certification program in quality assurance and quality control inspection of GCL installations.

Costs

As of 1994, the cost of an installed GCL ranged from $0.42

to $0.60 per square foot. Factors affecting the cost of a GCL include:

* Shipping distance
* Size of the job
* Market demand
* Time of the year

In general, GCL barrier systems are especially cost-effective in areas where clay is not readily available for use as a liner material.

ISSUES TO BE ADDRESSED

This emerging technology requires additional field and laboratory testing to further assess its effectiveness as a landfill barrier system in terms of the key performance factors discussed below. Improved product design and installation standards must also be established.

Performance Factors

Further research is needed into the following key performance factors of GCLs:

* Hydraulic Conductivity: Available data on the hydraulic conductivity of various GCL configurations are gathered exclusively under laboratory conditions. Data from field tests should be collected to establish product design values.

* Bearing Capacity: A study by the Geosynthetic Research Institute provides the basis for allaying some concerns about the bearing capacity of hydrated GCLs, but more research is needed. The study demonstrated that an adequate layer of cover soil (according to the product manufacturers' recommendations), placed on GCLs during installation, prevents a decrease in liner thickness with the application of a load. Without a sufficient soil layer, GCLs become compressed, raising their hydraulic conductivity (i.e., making them more permeable) and

reducing their effectiveness as a barrier.

* Slope Stability: Research is ongoing on the slope stability of GCLs used in landfill sidewall applications to determine whether this use of GCLs provides sufficient resistance to internal shear and physical displacement. Additional data are needed to support the preliminary results of a U.S. Environmental Protection Agency field study indicating good stability of GCL technology following capping operations. This study mimicked the construction stresses all four GCL products (see Figure 3 - To view Figure 3, see pdf version of this document.) are subjected to during capping. Constructed in November 1994, the study site used five plots of GCL placed at a 3 to 1 slope and eight plots placed at a 2 to 1 slope. All plots had a 3-foot-thick soil cap. Researchers collected information on the soil and clay moisture of the GCL using internal probes, and they measured the GCL for physical displacement. Results to date indicate good slope stability for all plots.

* Long-Term Reliability: The geotextile or geomembrane in GCL products remains durable for long periods of time.

* Freeze and Thaw Cycles: Freeze and thaw cycles do not affect GCLs used in landfill bottom liner applications because these systems are installed below the frost line. Limited laboratory data indicate that the hydraulic conductivity of GCLs is not affected by freeze and thaw cycles. Laboratory tests performed on a bentonitic blanket indicate that hydraulic conductivity before freezing of 2 x 10-11 cm/sec was unaltered after five freeze and thaw cycles. Full-scale field tests still must be conducted, however, to corroborate the laboratory data, especially for GCL technology used as an infiltration barrier in landfill caps.

Design and Installation Standards

The following issues must be addressed to encourage the further development of GCL technology as a landfill barrier system:

* Material Properties and Additional Testing Methods: To allow design engineers to develop more precise site specifications, a list of important performance properties for materials used in GCL products, as well as minimum performance values, must be established. Additional testing procedures must be developed, and all methods should be standardized to facilitate the realistic comparison of different GCL products.

* Construction and Installation Procedures: Standardized practices must be developed to address GCLs' vulnerability to the following:

  -- System stress from inclement weather after installation.

  -- Potential for lack of hydration of bentonite clay in arid regions.

  -- Punctures in the barrier system (reducing the barrier potential of both the clay and the geosynthetics).

  -- System decay caused by biological intruders, such as burrowing animals and tree roots (potentially affecting both the clay and the geosynthetics). Additionally, a standardized quality assurance and quality control program must be developed.

CASE STUDIES

The following case studies illustrate some of the uses of GCL technology as a barrier system in landfills. Currently available information from these sites relates to installation only; long-term performance is still being assessed. Only one of the studies concerns the use of GCL technology in bottom liner applications, because this use is relatively new. The other two studies focus on cap system applications, which represent a slightly more established use of the technology. The case studies represent sites in three different geographic regions and involve three different GCL products.

GCL LANDFILL LINER:
Broad Acre Landfill
Pueblo, Colorado

Broad Acre Landfill installed a liner system in 1991 that included:

* A 60-mil Gundseal GCL
* 1 foot of compacted clay

According to landfill operators, the Gundseal was easy to work with. They installed 200,000 square feet in 1 week. Workers installed the liner with the bentonite side down (i.e., the geomembrane side up). As of February 1996, landfill officials reported that the liner was functioning effectively. No releases of leachate have been detected by the ground-water monitoring system.

GCL LANDFILL CAP:
Whyco Chromium Landfill
Thomaston, Connecticut

During July 1989, Whyco Chromium Landfill installed a Claymax 200R GCL in a cap system that included the following (from top to bottom):

* 6 inches of topsoil
* 24 inches of earthen material
* Geogrid (for tensile strength)
* Geotextile
* Polyvinyl chloride geomembrane (30-mil thickness)
* Claymax
* Geotextile

The landfill site occupies 41,000 square feet, and workers installed the Claymax product in 1 day. Thus far, the cap is functioning well.

GCL LANDFILL CAP:

Enoree Landfill
Greenville, South Carolina

In August 1994, the first phase of closure at the Enoree Landfill involved installing the following cap system:

* 6 to 12 inches of new and native soil
* 18 inches of compacted clay
* Bentofix GCL

Enoree staff capped approximately 26 acres of the landfill in 6 weeks. Landfill officials report that the cap is functioning effectively.

The mention of publications, products, or organizations in this fact sheet does not constitute or imply endorsement or approval for use by the U.S. Environmental Protection Agency.

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