"GEOSYNTHETICS CONQUER THE LANDFILL LAW"

Lopez Canyon Landfill near Los Angeles underwent a 4-million m^3 expansion using innovative materials in the liner system to overcome difficult site conditions. The side slopes are up to 90 m high and had been graded by the city's workforce to provide slopes of between 1:1 and 1.5:1 with benches every 12-m in height. The steep side slopes made the prescribed Subtitle D liner (geomembrane plus 60 cm of compacted clay) technically and economically prohibitive.

An alternative side-slope liner design was developed utilizing from bottom to top; a reinforced air-sprayed slope veneer (ASSV), reinforced geosynthetic clay liner, HDPE geomembrane, geonet, geotextile and a 0.6 m thick operations layer. The ASSV of concrete averaged 75-100 mm thick and was reinforced with 17-gauge hexagonal netting wire. A reinforced GCL was used in lieu of compacted soil for the low permeability soil component of the composite liner. A GCL has many advantages over a compacted soil liner including simple construction methods for installation, no water consumption, low dust generation (when using a granular bentonite), low susceptibility to desiccation, self-healing if punctured, tensile strength and limited loss of air space. A geonet was used in lieu of granular material to provide a leachate collection layer for the side-slope liner system. Geonets allow a high level of drainage capacity. To protect the geonet from degradation due to infiltration of particles from the overlying soil or waste, a nonwoven geotextile was placed over the geonet.

The State required that the liquid-containment capability of the two liner systems (Subtitle D and alternative) be compared. The results indicated that the theoretical flux of leachate through the alternative liner system was more than 40 times less than through a Subtitle D liner subjected to a maximum head of 0.3 m.

The changes in design also required a reassessment of landfill stability. Interface shear tests were performed to evaluate the shear strength of the alternative liner. The test showed that the weakest interface in the alternative side-slope liner system would be the geonet/smooth geomembrane interface.

TR 207
2/01

GEOSYNTHETICS CONQUER THE LANDFILL LAW

LUTHER DERIAN
KELLY M. GHARIOS
EDWARD KAVAZANJIAN JR.
MICHAEL S. SNOW

Los Angeles' last operating landfill is undergoing a 4 million m^3 expansion using innovative materials in the liner system to overcome difficult site conditions. The design represents the first approved alternative in California—and perhaps in the nation—to the Resource Conservation and Recovery Act's Subtitle D regulations for liner systems. Here's a look at the regulatory journey that led to approval and the liner's design and construction.

Steep slopes at Los Angeles' only operating municipal solid-waste landfill (MSW) forced designers to use an innovative geosynthetic liner and leachate collection system. Its use sets a precedent for alternatives to the prescriptive regulations for liner systems present in Subtitle D of the Resource and Conservation Recovery Act (RCRA). To provide uninterrupted service at the landfill, design and construction proceeded concurrently with regulatory approval.

The Lopez Canyon Landfill, located in the foothills of the San Gabriel mountains about 50 km northwest of downtown Los Angeles, has been in operation since 1975, and has a total capacity of about 18.6 million t of refuse. At the 1990 disposal rate of 3,600 t per day, the landfill would have exhausted its permitted capacity by November 1992. To extend the life of the existing units and meet future solid-waste disposal needs, the Solid Waste Management Division (SWMD) of the Los Angeles Bureau of Sanitation embarked on a program of waste diversion, source reduction and recycling, and development of the final landfill cell, disposal area C.

Disposal area C covers about 15 ha of land. The side slopes are up to 90 m high and have been graded by the city's work force to provide slopes of between 1 horizontal to 1 vertical and 1.5H:1V with benches every 12 m in height. To be ready to receive waste by summer 1993, officials at SWMD divided the construction of disposal area C into two phases. They awarded phase 1, covering an area of about 8 ha, in September 1992, with completion scheduled for May 1993, and receipt of waste set for July 1993.

The steep side slopes at the Lopez Canyon Landfill rendered construction of the liner system prescribed by the new regulations technically and economically prohibitive. Instead, the city's staff and consultants developed an innovative alternative side-slope liner system made entirely of geosynthetic materials. Due to the city's urgent need for additional waste-disposal capacity, construction of this alternative liner system proceeded simultaneously with the quest for approval under some untried performance standard provisions of the new regulations.

Much of the work is being done by the city work force. The construction cost for the phase 1 liner installation was about \$3 million. Phase 2 liner construction will cost \$3.5 million. The city has moved four million m^3 of earth, at a cost of about \$10,000, as part of disposal area C development. Total cost of operating disposal area C for the next three years, including construction, operation, closure and postclosure maintenance, is estimated to be \$40 million–\$50 million.

THE REGULATORY CHALLENGE

Designers had initially designed the liner system in accordance with standards that were in effect in California in 1992. They presumed that the state's existing standards for MSW landfills, which contained performance criteria equivalent to or more stringent than the Subtitle D criteria, would be found by EPA to be in compliance.

In early 1993, EPA informed California that its existing state regulations were insufficient. The Los Angeles Regional Water Quality Control Board (RWQCB), enforcers of the state regulations for landfill liners, subsequently informed SWMD that, effective October 1993 and until California had an EPA-approved regulatory program, they would require strict conformance with Subtitle D standards. This requirement applied to disposal area C, even though the original containment system design had previously been approved by RWQCB and phase 1 construction already had begun.

The Subtitle D prescriptive standard for

0885-7024-/93-0012-0050/\$01.00+15¢ per page

DISPOSAL AREA C OF THE LOPEZ CANYON LANDFILL COVERS ABOUT 15 HA. STEEP SIDE SLOPES AT THE LANDFILL RENDERED CONSTRUCTION OF A LINER SYSTEM, AS PRESCRIBED BY FEDERAL REGULATIONS, TECHNICALLY AND ECONOMICALLY PROHIBITIVE, PROMPTING THE SEARCH FOR AN ALTERNATIVE.

FIG. 1. SIDE-SLOPE LINER SYSTEM DETAIL

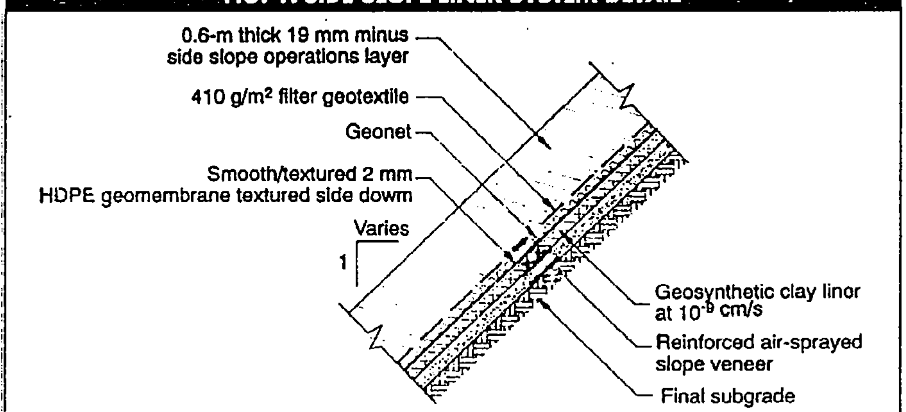
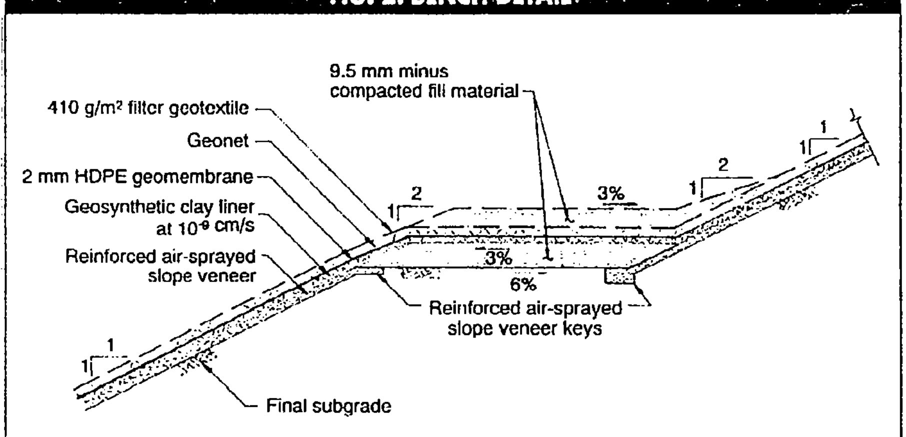


FIG. 2. BENCH DETAIL



containment systems includes a composite liner and a leachate collection and removal system (LCRS). The liner should consist of a minimum of 0.6 m of compacted soil with a permeability of less than 1×10^{-7} cm/s overlain by a geomembrane with a minimum thickness of 0.75 mm, or 1.5 mm if high-density polyethylene (HDPE) is used. The LCRS must be designed to prevent a leachate head of more than 0.3 m from accumulating.

The performance standard establishes the maximum allowable impacts by the landfill on the ground water. A state can only grant approval for designs under the performance standard after its regulatory program has been approved by EPA. However, Subtitle D does contain provisions under which states can submit petitions to EPA for approval of alternative designs under the performance standard.

Strictly speaking, the portions of disposal area C in which waste would be placed before the October 1993 effective date were not subject to the new Subtitle D liner regulations. SWMD officials decided, however, to modify the liner system for all of disposal area C, including phase 1, to comply with the Subtitle D regulations.

Design of an alternative liner and leachate collection system on the canyon side slopes presented two primary challenges. First, granular drainage materials for the leachate collection layer were subject to stability problems and would be difficult to place. Second, the construction of a 0.6 m thick low-permeability soil layer was prohibitive from both schedule and construction perspectives. Due to these constraints, designers from GeoSyntec Consultants, Huntington Beach, Calif., proposed an alternative side-slope liner system made with geosynthetic components.

In February 1993, officials with RWQCB said they would approve an engineered alternative liner system if it could be demonstrated that the waste-containment capability of the liner system equaled or exceeded the containment capability of the Subtitle D prescriptive liner system. They further agreed to petition EPA for approval of the alternative liner system design as a precaution in case the California regulatory program did not obtain EPA approval in a timely manner. Phase 1 had to be finished by summer 1993, so SWMD officials decided, after consultation with GeoSyntec Consultants, to risk proceeding with design and construction while concurrently pursuing regulatory

AN INNOVATIVE DESIGN

The original base liner system design had a 0.3 m thick leachate collection layer over a composite liner consisting of 0.45 m of compacted soil with a permeability of less than 1 x 10^{-6} cm/s covered by a 2.0 mm thick HDPE geomembrane. The original side-slope liner system design consisted of a single 2.0 mm thick HDPE geomembrane with a cushion geotextile on top. A veneer of shotcrete with a compressive strength of 170–205 kPa (25–30 psi) would be sprayed onto the graded canyon side slopes to provide a smooth surface for the geomembrane liner placement.

Three major modifications were required to bring the liner system into compliance with Subtitle D standards: Increase the thickness and decrease the permeability of the low-permeability soil component of the base composite liner; install a composite liner instead of a single geomembrane for the side-slope liner system; and incorporate a leachate collection layer into the side-slope liner system design. In addition to these requirements, SWMD directed GeoSyntec designers to use recycled materials wherever possible.

Material for the low-permeability soil omponent of the base composite liner (to increase the thickness from 0.45 m to 0.6 m) was readily available on site. Test-pad permeability values, however, indicated that this material would not meet the maximum permeability criterion. Bentonite, used as a soil amendment, lowered the permeability. Crews constructed a series of three test strips constructed with 0%, 2%, and 4% calcium bentonite (by weight) to determine the appropriate bentonite content. They constructed a test strip without bentonite for correlation with the preconstruction test-pad results. Use of a nominal bentonite content of 2% resulted in most, but not all, samples meeting the permeability standard. After adding 4% bentonite, all specimens recovered for laboratory testing had a permeability less than the maximum allowable value. Based on these results, crews constructed the low-permeability soil component of the composite liner using 4% percent bentonite by weight.

The primary challenge in redesigning the containment system was the development of an alternative composite side-slope liner system. From top to bottom, this liner system consists of a 0.6 m thick "operations" layer of soil to protect the liner system from the waste placement; a 410 g/m^2 filter geotextile; a geonet drainage layer; a 2.0 mm thick high-density polyethylene geomembrane, with a smooth side facing up and a textured side facing down; a geosynthetic clay liner (GCL) that serves as the low-permeability soil component of the composite liner; and an air-sprayed slope veneer (ASSV) of concrete averaging 75–100 mm thick and reinforced with 17-gauge hexagonal netting wire.

Designers used the GCL in lieu of compacted soil for the low-permeability soil component of the composite liner. A GCL is composed of a thin (about 6 mm) layer of sodium bentonite, which is either adhered to a geomembrane or placed between two geotextiles. The sodium bentonite has a typical permeability on the order of 1 x 10^{-9} cm/s to 5 x 10^{-10} cm/s.

> **Theoretical flux through the alternative liner system was 40 times less than through a Subtitle D liner.**

A GCL has many advantages over a compacted soil liner including simple construction methods for installation, low water consumption and low dust generation during construction, low susceptibility to desiccation cracking, self-healing abilities if punctured, material quality maintained in a controlled environment, low permeability, tensile strength developed by the geomembrane or geotextiles, and limited loss of waste-storage capacity.

Designers used a geonet in lieu of granular material to provide a leachate collection layer for the side-slope liner system. Geonets are composed of plastic strands and allow a high level of drainage capacity. To protect the geonet from degradation due to infiltration of particles from the overlying soil and waste, they placed a nonwoven filter geotextile over the geonet. Engineers at the GeoSyntec Consultants Materials Testing Laboratory, Boca Raton, Fla., showed that the geonet could provide the necessary drainage capacity under the anticipated loading conditions.

RWQCB required that the liquid-containment capability of the two liner systems (the proposed geosynthetic alternative and the Subtitle D system) be compared. The results of the evaluation indicated that the theoretical flux of leachate through the geosynthetic alternative liner system subject to a site-specific leachate head was more than 40 times less than through a Subtitle D liner subject to the prescriptive maximum head of 0.3 m.

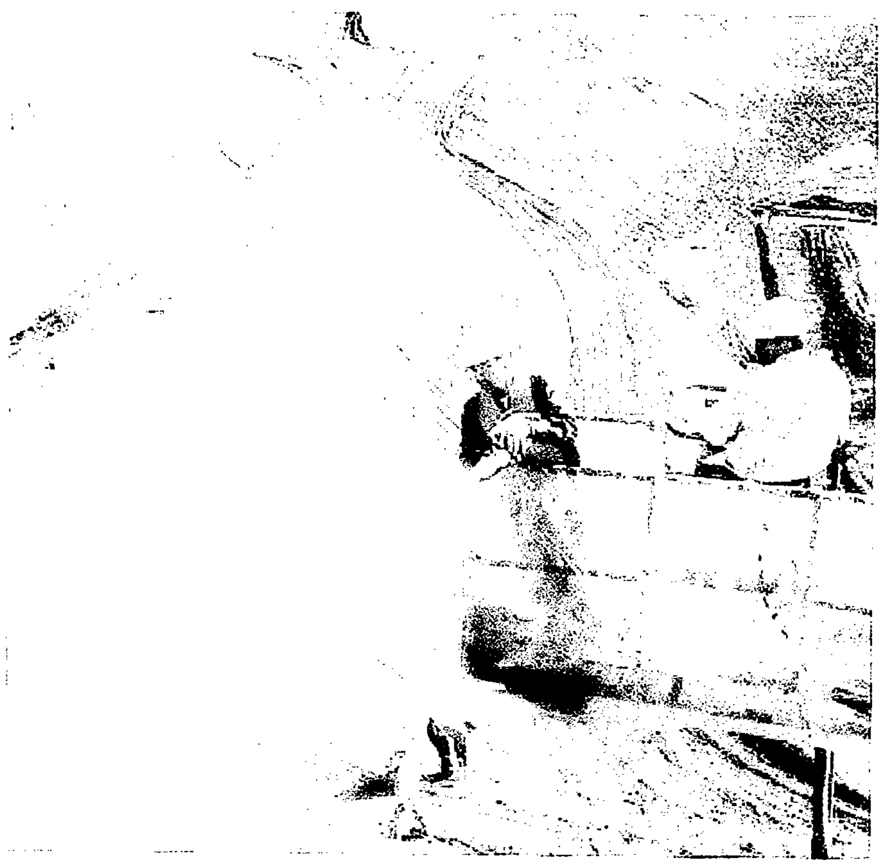
The changes in the preapproved liner system required a reassessment of landfill stability. Engineers performed interface shear tests to evaluate the shear strength of the bentonite-amended base liner system and the geosynthetic side-slope liner system at the GeoSyntec Consultant's Geosynthetics Interaction Laboratory, Atlanta. The test showed that the weakest interface in the alternative side-slope liner system would be the geonet/smooth geomembrane interface, but that this interface would be stronger than the weakest interface in the original design.

Designers submitted the petition to RWQCB for approval of the alternative liner system in April 1993. Phase 1 construction, using the alternative design, had already resumed.

CONSTRUCTING THE LINER

Construction of phase 1 by general contractor Foster Wheeler Enviresponse, Santa Fe Springs, Calif., began in November 1992. The initial stage involved subgrade preparation and installation of the ASSV and subdrain collection system.

In April 1993, the contracting team began work on the amended clay soil liner in the base areas. Approximately 1,100 t of calcium bentonite, obtained from a mine near Victorville, Calif., were incorporated into the clay liner. Crews spread bentonite over 280–310 mm thick uncompacted lifts of the clayey silt borrow soil with a calibrated spreader truck. They subsequently mixed the bentonite into the soil using specially adapted road-reclaiming equipment developed by subcontractor J.A. James Construction, Ontario, Calif. The road reclaimer was fitted with teeth to mix the soil and bentonite while pulverizing oversized clods. Operators made three initial passes without adding any water. On the fourth pass, they added water during the mixing process directly from the road reclaimer, which resulted in a uniform mixture of moisture and bentonite.



E LANDFILL'S CONCRETE AIR-SPRAYED SLOPE VENEER HAS AN AVERAGE THICKNESS BETWEEN 75 MM AND 100 MM AND IS REINFORCED WITH 17-GAUGE HEXAGONAL NETTING WIRE.

Crews compacted the amended soil liner with a sheepsfoot static compactor. After completing each lift, they evaluated compaction, plasticity, particle size and permeability as part of their construction quality assurance program. Workers measured permeability on site with an in situ probe and, in the laboratory, with thin-walled tube samples. The test results indicated that the amended clay liner had a permeability ranging from 9×10^{-8} to 2×10^{-9} cm/s, in conformance with the Subtitle D requirement of less than 1×10^{-7} cm/s.

Crews constructed approximately 19,000 m^3 of amended clay liner over a four-week period. The final lift was rolled with a smooth roller compactor and regularly sprayed with water to control desiccation cracking.

High temperature variations, winds, and steep slopes affected the construction of the geosynthetic side-slope liner system. It helped that the geosynthetics installer, the National Seal Co., Aurora, Ill., had worked under similar conditions prior to this project. Geosynthetics installation in the side-slope areas took place from April to June. A total of 15,500 m^2 of geosynthetic compos-

Initially, the installer concentrated on the geosynthetic clay liner and geomembrane, overlapping the GCL as each panel was rolled down the slope along premarked lines on the GCL surface. Placement and alignment of the textured geomembrane over the GCL required a slip sheet (in this instance a geonet) to avoid sticking between the GCL and geomembrane. Crews rolled the geomembrane down the slope with the slip sheet placed between the GCL and the geomembrane. Once the geomembrane was positioned properly, they pulled out the slip sheet from under the geomembrane. When the GCL and geomembrane were in place, they laid the geonet and filter geotextile. The installation crews overlapped and attached the geonet with white plastic ties that would be easily observed against the black geomembrane background. Then they sewed the geotextile along the seams.

Installation of the geosynthetic side-slope liner proceeded smoothly. All geomembrane seams were nondestructively tested, and samples were recovered for destructive conformance testing. Some problems did arise toward the end of phase

the canyon floor sometimes exceeded 38C. Progressive downslope movement, from expansion and contraction of the geomembrane due to the large diurnal temperature change, caused some "trampolining" of the geomembrane on the lowest bench (the membrane bridged across the bench, lifting off the bench surface).

The downslope movement also caused several large wrinkles to develop at the toe of the slope. Crews removed and repaired the wrinkles and placed the drainage gravel and operations layer at the toe and backfill on the bench. Such difficulties emphasized the importance of coordination between the installation of the geosynthetics and the placement of backfill over the liner system.

Containment-system construction for phase 1 was completed in June. That same month, the California Integrated Waste Management Board approved the permit for disposal area C, although commencement of disposal operations still required approval of the alternative liner design and certification of liner construction by RWQCB.

In July, RWQCB informed the SWMD that the petition for the alternative liner system had been approved and forwarded to EPA. EPA returned the petition to RWQCB without comment, noting that recent modifications to California's MSW landfill regulations were sufficient for the state to be approved for compliance with Subtitle D, rendering EPA approval of the petition unnecessary. On July 21, RWQCB provided the final approval required for waste-disposal operations to begin when it accepted certification of construction of the containment system for phase 1-of disposal area C from GeoSyntec Consultants. Phase 2 construction is under way and will continue through April 1994.

Building an innovative, state-of-the-art disposal facility has required close cooperation between the owner, consultant, contractor and regulatory agencies. The result will be highly protective of the environment and provide for Los Angeles' solid-waste disposal needs without interruption.

Luther Derian, P.E., is an assistant division engineer with the Los Angeles Bureau of Sanitation's Solid Waste Management Division. Kelly M. Gharios, P.E., is a sanitary engineer with the division. Edward Kavazanjian Jr. is an associate and Michael S. Snow, P.E., is a senior project engineer with GeoSyntec Consultants, Huntington Beach,