Geosynthetic Composite Liner System for Steep Canyon Landfill Side Slopes

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ABSTRACT: The City of Los Angeles (City) Lopez Canyon Sanitary Landfill was recently expanded to meet the City's municipal solid waste (MSW) disposal needs. The expansion occurred in a natural canyon graded to provide a relatively flat base with steep benched side slopes. On the side slopes at Lopez Canyon, the use of the prescribed composite liner system in California and federal regulations was not feasible due to the steepness of the slopes. As a result, an alternative design composed of geosynthetic elements was adopted and implemented. A geosynthetic clay liner (GCL) was used instead of the compacted low-permeability soil to form the lower component of the composite liner. Leachate drainage capacity was provided by use of a geonet overlain by a geotextile filter on top of the geomembrane. The leachate containment capability of the geosynthetic alternative liner system was shown to exceed that of the prescribed liner system, thereby satisfying regulatory requirements for alternative designs.

1 INTRODUCTION

The Lopez Canyon Sanitary Landfill, located in the foothills of the San Gabriel mountains about 50 km northwest of downtown Los Angeles, is the City of Los Angeles' only operating municipal solid waste (MSW) landfill. The landfill has been in operation since 1975 and has a total capacity of about 18.6 million tonnes metric of refuse. To meet future solid waste disposal needs, the City undertook development of a new landfill cell in 1991, known as Disposal Area C.

Disposal Area C covers a plan area of about 15 hectares and is located in a natural canyon. The side slopes of Disposal Area C are up to 90-m high. Following development of the Master Plan and preliminary engineering for the landfill expansion, the City's work forces graded the side slopes to inclinations between 1H:1V (horizontal:vertical) and 1.5H:1V, with 5-m wide benches every 12 m in height.

Subsequent to the grading of Disposal Area C, the State of California implemented new federal criteria for liner systems at MSW landfills. In the federal criteria, two types of liner system designs are allowed either: (i) a prescriptive minimum construction standard; or (ii) a site-specific alternative design that meets a performance standard.

The prescriptive minimum construction standard for MSW landfill liner systems is comprised of a 0.6 m-thick layer of compacted low permeability soil with a saturated hydraulic conductivity no greater than 1 x 10^{-7} cm/s overlain by a synthetic membrane at least 1.0-mm thick, or 1.5-mm thick if HDPE is used, overlain by a leachate collection and removal system (LCRS). The LCRS must be designed to limit the liquid head on the liner system to a maximum of 0.3 m.

The steepness of the Disposal Area C side slopes rendered construction of the low permeability soil component of the prescriptive liner system impractical from cost, schedule, and constructibility standpoints. The steep side slopes also made construction of a conventional granular soil LCRS system impractical. Due to these limitations, the City asked its engineering consultant for Lopez Canyon to develop an alternative design for the Disposal Area C side-slope liner system.

2 LOPEZ CANYON SIDE SLOPE LINER

To meet the challenge of designing a constructible composite liner system for the side slopes of Disposal Area C at the Lopez Canyon Landfill, an entirely geosynthetic composite liner and LCRS was developed. Fig. 1 shows a schematic cross section of the geosynthetic alternative developed for the side slopes of

Disposal Area C. From top to bottom, this alternative liner system consists of:

- a 0.6-m thick "operations" layer;
- a 410 g/m^2 nonwoven filter geotextile;
- a polyethylene geonet drainage layer;
- an 2.0-mm thick HDPE geomembrane, smooth on the top and textured on the bottom;
- a geosynthetic clay liner (GCL); and
- a reinforced air-sprayed slope veneer (ASSV) of concrete averaging 75 to 100 mm in thickness.

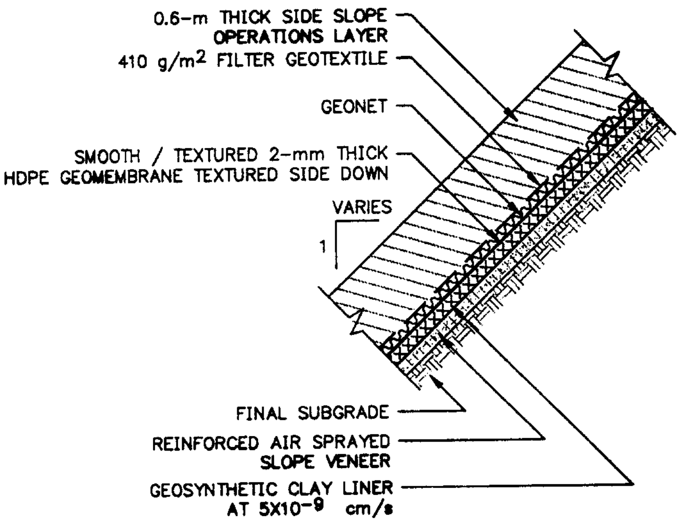

Fig.1 Alternative Side-Slope Liner System

The veneer of concrete was specified to have a compressive strength of 170 to 205 kPa and was sprayed onto the graded canyon side slopes to provide support and a smooth surface for the composite liner.

The GCL is used in lieu of compacted soil for the low-permeability soil component of the composite liner. A GCL is composed of a thin layer of sodium bentonite approximately 6-mm thick which is either sandwiched between two geotextiles or glued to the back of a geomembrane. A maximum saturated hydraulic conductivity ranging from 5 x 10^{-9} to 1 x 10^{-10} cm/s is typical of GCLs over the range of confining pressures typically encountered in practise.

A GCL has many advantages over a compacted soil liner including:

- simple installation and lower installed cost;
- low water consumption, dust generation, and vehicular traffic during construction;
- low susceptibility to desiccation cracking;
- self-healing capabilities if punctured;
- material quality maintained in a controlled environment;
- lower construction quality assurance costs;
- tensile strength developed by the geotextiles or geomembrane; and
- reduced loss of valuable waste disposal capacity.

For the Disposal Area C side slopes, the GCL was specified to have a maximum saturated hydraulic conductivity of 5 x 10^{-9} cm/s, contain 90 percent sodium bentonite at a density of 4.9 kg/m^2, and have minimum internal and interface friction angles of 10 degrees at confining pressures of up to 1,250 kPa.

A polyethylene geonet was used in lieu of granular soil to provide an LCRS on the side slopes. The primary advantages of the geonet are simple installation and a high drainage capacity. the high drainage capacity results in a low liquid head on the composite liner. The geonet was specified to have a transmissivity of 5 x 10^{-4} m^2/s under inclined pressures of 630 kPa. To protect the drainage capacity of the geonet from degradation due to infiltration of particles from overlying soil and waste, a nonwoven filter geotextile was placed over the geonet. The 410 g/m^2 geotextile was specified to meet minimum survivability requirements, have an apparent opening size of between 0.15 and 0.21 mm, and have a minimum hydraulic conductivity of 0.2 cm/s.

3 PERFORMANCE EVALUATION

A performance evaluation of the geosynthetic side slope liner design was performed to show that the alternative design met the regulatory performance standards. This evaluation included a demonstration that the leachate containment capability of the side slope liner was superior to that of the prescriptive standard. The steady-state rate of leachate migration through a hypothetical defect in the geomembrane component of a composite liner system subjected to a sustained leachate head was used as the quantitative basis for comparing the leachate containment capability of the federal prescriptive liner system to the alternative geosynthetic liner system. According to Giroud and Bonaparte (1989a,b), the steady-state leachate migration rate through a hypothetical defect in a composite liner is a function of the leachate head on the liner, the dimensions of the defect, and the performance characteristics of the liner.

The leachate head on the liner is a function of the leachate generation rate in the landfill and the hydraulic conductivity, slope gradient, and drainage path length of the LCRS. The leachate generation rate for Disposal Area C was estimated using the "*Hydrologic Evaluation of Landfill Performance*," or "*HELP*," model, Version 2, developed for the United States Environmental Protection Agency (USEPA, 1984a,b). Leachate generation rates were calculated for short-term interim, long-term interim, and post-closure conditions. The short-term interim condition, consisting of 15 m of waste subject to two consecutive years of twice the average annual rainfall, produced the highest leachate generation rate. Using the estimated short-term interim leachate generation rate, the leachate head on the existing side-slope liner system was calculated using the methodology developed by Giroud (1992).

Steady-state leachate migration rates were calculated using the methodology developed by Giroud and Bonaparte (1989a,b) for both the alternative geosynthetic side-slope liner subject to the short-term interim operating conditions and the prescriptive liner subject to the maximum allowable head of 0.3m. The steady-state leachate migration rate through the alternative geosynthetic side-slope liner system for Disposal Area C at the Lopez Canyon Sanitary Landfill under short-term interim operating conditions was calculated as 0.006 liters per defect per day (lpdd), over 65 times less than the computed leachate migration rate for the prescribed liner system. A more detailed presentation of the performance evaluation for the Disposal Area C alternative side-slope liner system is presented in Snow et al. [1994].

4 BENCH ANCHORS

Anchoring of the liner system on the steep side slopes was provided on each bench. Instead of traditional anchor trenches, the liner system was anchored by backfill placed on top of the liner system lain flat across the bench surface. This type of bench anchor eliminated the need for excavation into the bedrock and the stress concentrations that may be induced in the geosynthetic components by an anchor trench. The bench backfill also allowed for access to the side-slopes and interim surface-water drainage control along the benches.

5 GEOSYNTHETIC TESTING PROGRAM

Geosynthetic testing was performed for design and construction quality assurance purposes. The testing program included interface shear strength tests on the geosynthetic side-slope liner system, transmissivity testing of the geonet, hydraulic conductivity testing of the GCL, conformance testing of the nonwoven geotextile and HDPE geomembrane, and nondestructive and destructive testing of the HDPE geomembrane seams.

Tests performed during design included interface shear testing of the GCL/textured geomembrane interface and on the entire side-slope liner system "sandwiched" under both dry and saturated conditions at normal pressures of up to 450 kPa. The results of these tests are summarized in Table 1.

These shear strength results were used to confirm that the interim and long-term behaviour of the waste pile would not adversely affect the performance of the liner system under both ststic and dynamic loading conditions.

Table 1 Interface Shear Test Results

Test Setup	Peak Friction Angle (deg.)	Peak Adhesion (kPa)
Liner Sandwich (soaked)	7	7.5
Geonet/Smooth HDPE	13	21.8
GCL/Text. HDPE (soaked, high stress)	9	0
GCL/Text. HDPE (soaked, low stress)	18	0
GCL/Text. HDPE (dry, high stress)	19	0

Specialized laboratory testing demonstrated that the geonet could provide the necessary transmissivity of 5 x 10^{-4} m^2/s. Normal pressures as high as 1,260 kPa were applied in the laboratory to the soil/geotextile/geonet/geomembrane sandwich. These specialized conformance tests accounted for the potential compression and rotation of the geonet strands and intrusion of the geotextile into the voids of the geonet. Test results indicated that transmissivities ranging from 1.28 x 10^{-3} to 1.51 x 10^{-3} m^2/s were obtained.

6 CONSTRUCTION

Construction of the geosynthetic side-slope liner system was impacted by large temperature variations, high winds, and the steep slopes at the site. The familiarity of the geosynthetics installer with these conditions from his work on other landfills in the area was a significant benefit to the project. A total of about 15,500 m^2 and 77,000 m^2 of geosynthetic composite side-slope liner system was placed during Phase I and II of liner system construction, respectively.

A stitched woven/woven and a needlepunched woven/nonwoven GCL were used for Phase I and II liner system construction, respectively. The GCL was overlapped as each panel was rolled down the slope, using pre-marked lines on the GCL surface. The Phase I GCL joints were simply overlapped with no additional preparation, while the Phase II GCL joints were prepared by the addition of powdered bentonite at the rate of 1.5 kg/m^2 in the overlap areas. Placement and alignment of the geomembrane with the textured side down over the GCL required the use of a "slip-sheet" due to the "velcro" effect between the GCL and geomembrane. The geomembrane was rolled down the slope with the "slip-sheet", a geonet in Phase I, a visqueen sheet in Phase II, placed between the GCL and the geomembrane. Once the geomembrane was positioned properly, the "slip-sheet" was pulled out from under the geomembrane. Geomembrane panels were fusion welded and non-destructively tested using either air-pressure or vacuum box methods. Once the GCL and geomembrane were in place, the installer placed the geonet and nonwoven filter geotextile.

All geomembrane seams were non-destructively tested, and samples were obtained for destructive seam testing. Installation of the geosynthetic side-slope liner proceeded relatively smoothly. Some difficulties did arise toward the end of the first phase of construction, when daytime temperatures on the canyon floor exceeded 38 degrees Celsius. The progressive downslope movement that resulted from expansion and contraction of the geomembrane caused some "trampolining" of the geomembrane to occur on the lowest bench (i.e., the membrane bridged across the bench, lifting off the bench floor) and some large wrinkles developed at the toe of the slope. The solution to this problem included removal and repair of the wrinkles at the toe followed by placement of the drainage gravel and operations layer at the toe and backfill on the bench. Such difficulties emphasized the need to properly coordinate the installation of the geosynthetics and the placement of backfill over the liner system. A more detailed discussion of the design and construction challenges is presented in Derian et al. (1993).

Performance of the liner system under dynamic loading was observed during the magnitude 6.6 Northridge earthquake that struck Los Angeles on 17 January 1994. The Lopez Canyon site is located less than 15 km from the earthquake epicenter. Nearby recording stations measured horizontal peak ground accelerations of up to 0.44 g. Observations made that same day indicated that the geosynthetic side-slope liner system performed very well. No evidence of transient or permanent displacements between the waste mass and the liner system were observed despite being subjected to about 67 percent of the design acceleration with 33 percent of the ultimate waste thickness in place.

7 SUMMARY AND CONCLUSIONS

This paper presents a case history of the design and construction of an entirely geosynthetic composite liner system on steep side slopes at the Lopez Canyon Sanitary Landfill. The geosynthetic liner system was developed as an alternative to the prescriptive liner system described in federal criteria and California regulations. A GCL was used as the low-permeability soil component of the composite liner. A geonet was used to create a leachate collection and removal layer on top of the geomembrane.

Conformance tests were performed on all the geosynthetic components of the side-slope liner system at Lopez Canyon to simulate actual site conditions. Specialized tests were performed to ensure that: (i) the GCL met the specified saturated hydraulic conductivity and interface shear requirements; and (ii) the geonet met the specified drainage capacity under high confining stresses.

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