PERFORMANCE OF A GEOSYNTHETIC LINER SYSTEM IN THE NORTHRIDGE EARTHQUAKE

The magnitude 6.6 earthquake that struck the Los Angeles area on January 17, 1994 was the first major earthquake to take place in the continental United States since Subtitle D regulations took effect. There were several MSW landfills within the zone of strong earth acceleration. Two of these landfills incorporated geosynthetic liner systems in their design.

The Lopez Canyon landfill was located less than 10 miles from the epicenter of the Northridge earthquake. This canyon landfill was designed with a reinforced GCL on the side slopes. The Phase I area of the facility was filled halfway up the third bench on the slope to a height of approximately 100 feet with a 2H:1V inclination on the waste face.

The ground acceleration caused some shallow cracking in the interim soil cover, but no evidence of movement was detected at the waste/liner interfaces. Thus, based on the observations made after the Northridge earthquake, the geosynthetic clay liner was determined to perform well during this major earthquake.

Performance of a geosynthetic liner system in the Northridge earthquake

An interview with
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Federal legislation under the Resource Conservation and Recovery Act (RCRA) mandating geosynthetic liner systems for lateral expansion and new construction of municipal solid waste (MSW) landfill facilities became effective Oct. 9, 1993.

This legislation, commonly referred to as Subtitle D, also defines seismic impact zones in which MSW landfill containment systems must be designed to withstand an earthquake ground motion intensity with only a 10 percent probability of being exceeded in a 250-year period. This intensity corresponds to an earthquake that occurs approximately once every 2,400 years.

The seismic impact zones defined by Subtitle D encompass roughly 40 percent of the continental United States, including large areas in the eastern and central United States where seismic design has not traditionally been of concern.

The magnitude 6.6 earthquake that struck the Los Angeles area on the morning of Jan. 17 was the first major earthquake to hit the continental United States since Subtitle D took effect.

There are several MSW landfills located within the zone of strong shaking from the earthquake, including at least two with geosynthetic liner systems. *Geotechnical Fabrics Report (GFR)* spoke with the designer of the liner system of one of these facilities, the city of Los Angeles Lopez Canyon sanitary landfill, shortly after the earthquake.

Edward Kavazanjian Jr., Ph.D., P.E., GeoSyntec Consultants, Huntington Beach, Calif., served as engineer of record for design of the Subtitle D liner system for Disposal Area C at the Lopez Canyon facility. Kavazanjian also served as co-principal investigator for a National Science Foundation-sponsored workshop on Seismic Design of Solid Waste Landfills in August 1993, and is a member of the Seismic Risk and Transportation committees of the American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering.

Phase I of Disposal Area C at the Lopez Canyon landfill (featured in the December 1993 issue of Civil Engineering magazine) was completed in July 1993 and first received waste in August 1993. *GFR* questioned Kavazanjian on the performance of the Phase I liner system during the Northridge earthquake and the impact of the earthquake on current knowledge about the seismic performance of MSW landfills and geosynthetic liner systems.

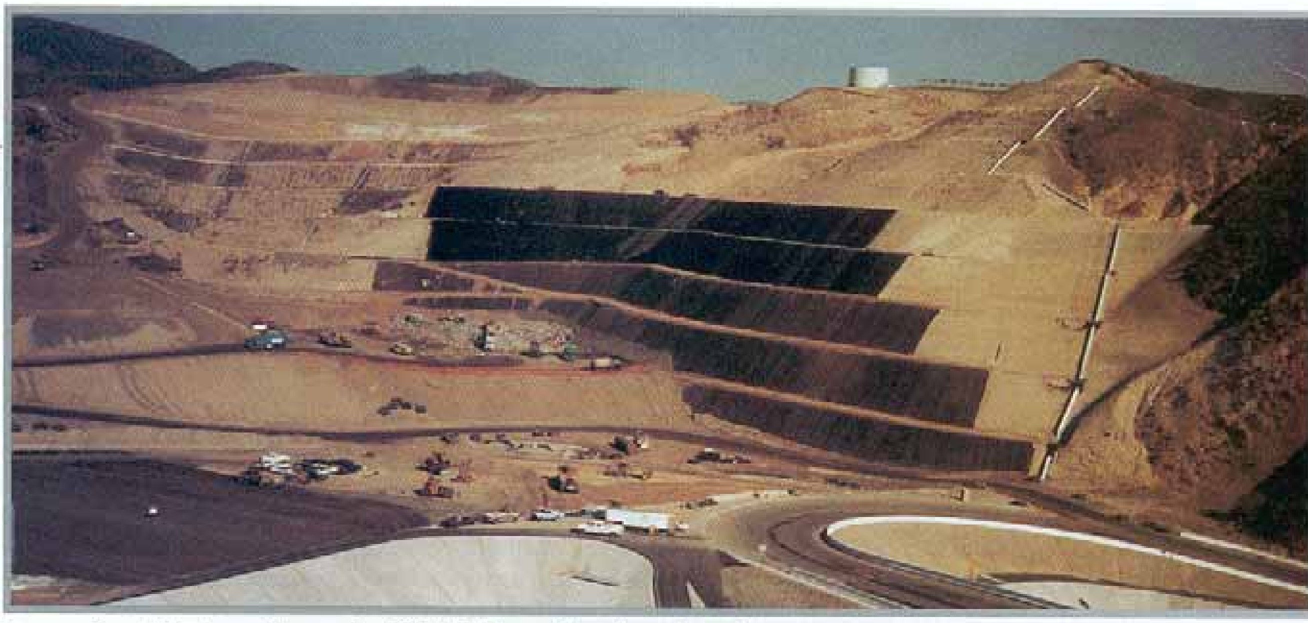
GFR: The performance record of MSW landfills in earthquakes is pretty good. What's all the fuss about?

EK: In general, landfills have performed well in past earthquakes, though the 1989 Loma Prieta earthquake was really the first time MSW landfills were subjected to a major earthquake in the United States. None of those landfills, however, was lined with a geomembrane. So, prior to the Northridge event, there was no record of performance of geosynthetic-lined landfills subject to strong shaking from an earthquake. Considering the stability problems that have occurred at lined waste disposal facilities even without an earthquake, the recent heightened attention to the seismic performance of lined landfills is not unwarranted.

The ground and geomembrane moved back and forth but the geonet, geotextile and backfill remained relatively motionless as slip occurred at the geonet/geomembrane interface.

GFR: Was the Lopez Canyon landfill subject to strong shaking in the Northridge earthquake?

EK: Without a doubt, yes! The landfill was less than 10 miles (15 km) from the epicenter of the event. Ground motion monitoring stations at two different nearby locations both mea-



An overview of the Lopez Canyon landfill eight hours after the earthquake.

sured a horizontal peak ground acceleration of 0.44 g (44 percent of gravity). That's a pretty strong shake!

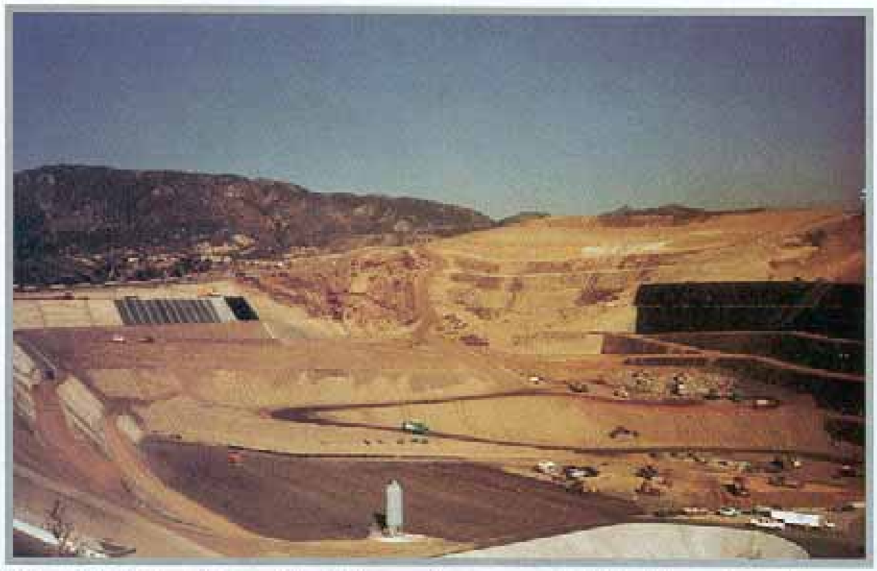
GFR: How did the landfill perform?

EK: Performance of the landfill was excellent, particularly with respect to the liner system. There was no evidence of either transient or permanent displacement between the waste mass and the liner system. There was some damage at the facility: landslides in the natural slopes outside the containment area, broken headers on the gas collection lines, office trailers knocked off their foundations, a broken water tank and buckled pavement at several locations—but there were no problems with the liner system.

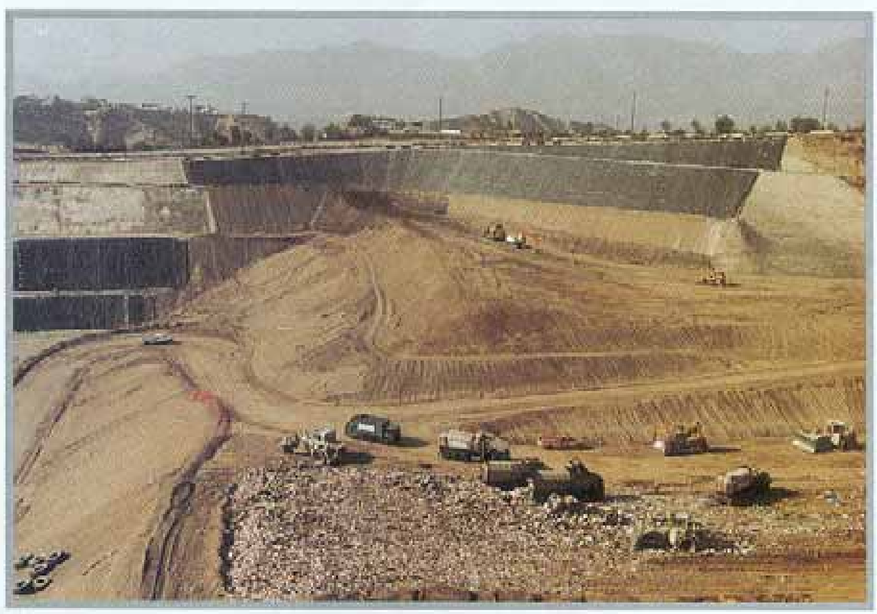
GFR: Can you describe the configuration of the liner system for us?

EK: There are actually two different configurations, one for the base of the landfill and one for the side slopes. The base liner meets the prescriptive requirements of Subtitle D, and includes (top to bottom) an 8 oz./yd. (270 g/m^2) filter geotextile, 12 inches (300 mm) of gravel, a 16 oz./yd.^{2} (540 g/m^2) cushion geotextile, an 80 mil. (2 mm) textured geomembrane, and 24 inches (600 mm) of clay.

The side slopes are quite steep, with a typical inclination of 1H:1V (horizontal to vertical) and 18-foot- (5.5-m) wide benches every 40 feet (12 m) in height. Because of the steep slopes, the side-slope liner system is an alternative system designed to meet Subtitle D performance standards. This side-slope liner system includes (top to bottom) a 12 oz./yd.^{2} (410 g/m^2) filter geotextile, a geonet, an 80-mil (2 mm) geomembrane (smooth on the upper face, textured on the lower face) and



Liner installation (left) and landfill operations one week before the earthquake.



Phase I area overview (eight hours after the earthquake).

a reinforced geosynthetic clay liner (GCL). The side slopes are lined to a height of 200 feet (60 m) above the canyon floor.

GFR: At the time of the earthquake, how much waste had been placed on the liner?

EK: At the time of the earthquake, the Phase I area was filled halfway up to the third bench (a height of approximately 100 feet) (30 m), and there was a 2H:1V inclination on the waste face. There was some shallow cracking in the interim soil cover at the crest of the waste face, but there was no evidence of movement at any of the waste/liner interfaces at the base or on the side slopes.

GFR: It sounds like you found the good performance of the liner system a little surprising. Were you surprised by it?

EK: No, not really. Gratified is a better word than surprised. The liner system wasn't tested to its full design capacity, as it was designed for a peak ground acceleration of 0.69 g from a magnitude 6.5 earthquake with 300 feet (90 m) of waste on the liner. So, the liner was only subjected to two-thirds of the design acceleration with the waste at one-third of its maximum height.

GFR: If this wasn't a true test, then what was so noteworthy about the response of the liner system to the earthquake?

EK: I wouldn't say it wasn't a true test. Perhaps the liner system was not tested to its design capacity, but the waste still got a pretty good jolt. This earthquake did provide the strongest shaking to which a Subtitle D liner system has ever been subjected. The analyses for the design earthquake predicted several inches of permanent displacement between the waste mass and the liner. So, the complete absence of any relative movement between the liner and the waste does provide us with a bench mark against which to evaluate our models to some extent.

GFR: What kind of lessons will we be able to draw from this bench mark?

EK: Importantly, the earthquake magnitude and the peak acceleration at the site were both greater than those associated with many of the seismic impact zones in the United States, including the entire East Coast. So, if nothing else, this earthquake does demonstrate that properly designed and constructed MSW landfills with composite liner systems can withstand some earthquakes of magnitude and intensity comparable to those specified by Subtitle D on the East Coast for waste heights of up to 100 feet (30 m).

GFR: That's a pretty narrow conclusion. Can't we draw any more general conclusions from this earthquake?

EK: We probably will eventually, but it would be premature to do so yet. We need to investigate and analyze in detail the response of Lopez Canyon and some of the other MSW landfills in the epicentral region before we can draw any specific conclusions.

GFR: How did the other landfills in the area perform in the earthquake?

EK: From the reports I have received, most of the other landfills in the area performed pretty well, though most of these are either unlined, clay lined, or further from the epicenter than Lopez Canyon. However, one other landfill in the epicentral region with a Subtitle D liner that I am aware of reportedly suffered a tear in the geomembrane.

Striations on liner showing geomembrane movement relative to the geonet.

The ground moved but the geonet and soil did not (base isolation) (photo taken seven hours after the earthquake).

GFR: Is this tear a cause for alarm?

EK: While not necessarily cause for alarm, it is cause for caution. It is a clear indication that concern over the seismic performance of geosynthetic liner systems for MSW landfills has not been unwarranted. I think we need to know more about the specifics of the situation to understand what happened there and the differences between that landfill and Lopez Canyon. Then perhaps, we can draw some more general conclusions about seismic design and performance of landfill liner systems.

GFR: Are there any other noteworthy observations from this earthquake that you can share with us?

EK: With respect to geosynthetics, there is one that comes to mind. On one of the benches where the liner was under construction, the backfill was piled loosely on the front of the bench on unanchored geotextile and geonet. The geonet was sitting on an anchored, smooth geomembrane.

After the earthquake, the fill was undisturbed. There were no signs of sloughing or spilling of fill over the edge, and yet striations in the dust and dirt film on the geomembrane indicated relative movement between the geonet and geomembrane of up to 6 inches (150 mm). This is a perfect example of the base-isolation potential of geosynthetic materials.

GFR: Exactly what do you mean by base isolation?

EK: The low frictional resistance of the geonet/geomembrane interface isolated the overlying backfill from the seismic motions. The ground and geomembrane moved back and forth but the geonet, geotextile and backfill remained relatively motionless as slip occurred at the geonet/geomembrane interface. Using geosynthetics to this effect, referred to as base isolation, can provide an extremely cost-effective method of protecting equipment and low-rise structures from damage caused by earthquake ground motions.

Laboratory tests demonstrating the potential application of geosynthetics for seismic base isolation have been presented by Kavazanjian, Hushmand and Martin in the proceedings of the Third U.S. Conference on Lifeline Earthquake Engineering in 1991 and by Yegian and Lahlaf (September 1992 *GFR*, "Geomembranes on Base Isolation," page 17). The observations made in this earthquake provide field verification of this application.

GFR: Back on the topic of landfills, do we now have the information needed to design liner systems to resist earthquakes, or is there still work that needs to be done to understand the problem?

EK: There are still many fundamental questions that need to be answered about the design and construction of MSW landfills to withstand earthquakes. And liner systems are not the only geosynthetic concern. Subtitle D mandates a geosynthetic cover over areas with a geosynthetic bottom liner.

GFR: Did we learn anything about the performance of geosynthetic cover systems in this earthquake?

EK: Unfortunately, no. Because geosynthetic cover systems were not yet in place at any of the landfill affected by the earthquake, the seismic performance of a geosynthetic cover system has yet to be observed.

GFR: To conclude, can you tell us what, in your opinion, is the single most important thing the industry can do to improve current practice for seismic design of liners and covers?

EK: Because of the problems associated with measuring the dynamic properties of waste and geosynthetic interfaces in the laboratory, the only way we can reliably determine them is through field observations and measurements. Unfortunately, to date only one landfill in the United States has been instrumented to record seismic response, and that landfill is not a typical MSW landfill.

To properly understand the behavior of modern MSW landfills in earthquakes, we need a substantial data base of observations and measurements of the response of MSW landfills in diverse regions and climates to a variety of earthquakes. Until those observations are available, considerable uncertainty will remain about the seismic performance of landfills. As long as this uncertainty remains, a certain amount of caution and conservatism is warranted in our designs. GFR