ROUGH DRAFT

Geosynthetics: Unique Tools for Todays Environmental Problems

by

Gregory N. Richardson
John A. Bove

Geosynthetics in environmental applications are generally identified with new landfills where the roles of geosynthetics in the form of membranes and drainage media for new waste landfills is generally accepted and well defined. Current EPA Minimum Technology Guidance documents defined in detail both minimum physical properties and performance requirements for such applications. A recent design manual prepared for EPA by S&ME (1) provides literally a cook book approach for such applications. But the role of geosynthetics can be even greater in remediation applications. Here engineers are restricted only by their design ability and knowlege of the flexibility offered by geosynthetics. We have attempted to integrate the use of geosynthetics in remediation work performed by our environmental division. The results are consistently cost effective.

One of our first unique environmental applications (2) was the use of geotextiles to enable a soil cap to be placed on a pond filled with organic mucks. The pond had been heavily fuel-contaminated and removal of this material had the pond had filled with uncontaminated sediments from the pond bottom. This application took inspiration from the early work of the late Allan Haliburton (3,4) who constructed dredge containment dikes over very soft sediments. In such applications, the geotextile provides sufficient reinforcement enable the soft sediments to support the fill being placed. The role of the geotextile is short lived in that the weight of the fill consolidates the sediments which increases their shear strength leading to an equilibrium condition independent of the geotextile.

More recently, in association with J.P Stevens, we developed a membrane to replace a clay cap proposed for a significant landfill in New Jersey. Lacking a source of clay at a reasonable distance from the landfill, the landfill operators desired to use available borrow materials and satisfy the regulatory requirement for a low permeability through the use of a membrane cap. The application was complicated, however, because the sideslope of the 95 foot high landfill were very steep and actually exceeded 2:1 slope in places. Concern was rightly expressed that any soil placed on top of the membrane would slide off during construction or during the first major rainfall. Our role was to develop a geosynthetic that would be stable at these slopes and more cost effective than the imported clay cap.

Our most recent marriage of geosynthetics and environmental remediation was spurred by the need to isolate an existing steel foundary slag pile from the flood waters of an adjacent river. Rising flood waters seasonally penetrated the slag pile and leached heavy metals and pickling acids from the wastes. Under EPA orders to isolate the slag pile, we developed design alternatives that included both conventional flood control structures and the proposed geosynthetic dike. The cost savings of the geosynthetic option was overwhelming, with the final estimated construction cost being less than half the next alternative.

The pond encapsulation was performed in 1983 and has remained intact todate. The landfill cap application is currently undergoing a major field test and has successfully survived hurricane rains. The flood water dike has only just been permitted by EPA Region 4, a first of its kind. We feel strongly that such geosynthetic applications can play a vital role in significant numbers of waste remediation projects.

Capping Contaminated Pond

The pond is shown in Figure 1 and contained significant amounts of diesel fuel from spilled from an adjacent truckstop. The pond was incapable of supporting fish and other aquatic life and on two occasions the accumulated fuel was burnt of the pond, see figure 1. An environmental study indicated that the contamination was concentrated in the shallow surficial deposits of muck and partially decayed organic matter with concentrations exceeding 1000 mg/kg. Based on this study and in agreement with Ohio EPA, the landowner, and the client it was decided to remove the contaminated deposits and subsequently close the ponds.

Removal of the contaminated deposits began with drainage of the pond using pumps, rerouting of recharge waters to the pond, and lowering of the spillway to prevent the water from rising to its original level. Excavation of the sediments within the pond had to be accomplished without damaging surrounding trees. To accomodate this process, an earthen ramp and work pad were built at the south end of the pond. From the work pad, a backhoe was used to remove the contaminated muck which was then replaced with fresh soil from a local construction site. The fresh soil was used to extend the working pad. As the fresh soil was dumped in, the sediment at the bottom of the pond was displaced away from the edge of the pond towards the center. When the final contaminated sediment had been removed, the pond was effectively divided in two by the work pad, figure 2, and the two resulting ponds were filled with the soft bottom sediments.

The north pond created measured 100 by 100 ft with an average depth of 15 ft, while the south pond measured 83 by 180 ft with and average depth of 25 ft. Each pond was filled with sediments containing as much as 88% water by weight. Because of the high water content, the muck could not be removed to a landfill or buried in situ without treatment. An economic analysis was made comparing the cost of solidifying the remaining muck and removal to a landfill as compared to stabilizing and consolidating the muck in situ using geotextiles. By using geotextiles to stabilize and solidify the muck, a savings of over $300,000 resulted.

The basic concept was to place all the muck in the south pond and use a geotextile to allow placement of a soil cover over the muck and then the weight of this soil cover would consolidate and thus dewater the muck as shown on figure 3. Design methods used in selecting the geotextile are relatively simple and have been clearly presented at a recent conference on reinforcement over soft sediments (5). The geotextile selected for this project was made by Carthage Mills and had a burst strength of 585 lb/in2. The geotextile was seamed by the manufacturer to provide a single panel sufficient in size to cover the south pond.

Prior to installation of the geotextile, the site around the south pond was prepared by grading the bank around the south pond to the same elevation as the muck and to match the surrounding topography. Two trenches were constructed on the south and west ends of the south pond to anchor the fabric. The fabric was then stretched over the pond and anchored (figure 4). Once the geotextile was in place, cover soil was end-dumped on the south and east surface of the geotextile adjacent to the pond (figure 4a) to complete the anchorage of the fabric. On the northern edge of the pond, a 1 ft layer of sand was placed on the fabric to provide drainage for the water squeezed from the muck and the area was then covered with 2 ft of soil (figure 4b).

Having anchored the geotextile around the perimeter of the pond, a 1 ft layer of sand was placed on the fabric to provide a path for the water draining from the muck. The sand was placed in a 5-ft strip placed around the ever decreasing perimeter of the pond ,figure 5. Finally a 2-ft layer of cover soil was placed over the sand to provide weight for consolidation and cover for closure. Since closure, significant water has been observed seeping from the sand drain. The cover remains intact despite of significant settlements and vegetation is beginning to return to the pond area.

Capping Steep-Sided Municipal Landfill

Just south of Newark and adjacent to the New Jersey Turnpike, the Meadowlands landfill contains mountains of municiple waste clearly visible from New York City. These mountains may be as high as 130-ft and have side slopes as steep as 1.7:1, figure 5. The Hackensack Meadowlands Development Commission is charged with closure of this facility and was faced with the prospect of bringing clay from as far as 100-miles away to construct a 1-ft cover over the estimated 2500 acres of landfill requiring closure. J.P Stevens approached us to aid them in the development of a membrane that would reduce the need for a clay layer and yet provide a stable base for overlying cover soils needed to support a vegetative cover. The problem obviously being the low coefficient of friction provided by available membranes generated a slip plane that caused slippage of the cover soils.

Past attempts to roughen the surface of membranes had resulted in a significant reduction in the tensile and puncture strength of the membrane. Since the surfaces of the landfill contain exposed rubble, rebar, and assorted projections that readily penetrate most membranes, such a reduction in strength would not be tolerable. Thus the increase frictional bonding must result in the reduction of already marginal strength and puncture properties of the membrane.

Working with Stevens, we developed a geosynthetic composite formed of a Hypalon membrane with a light weight nonwoven fabric bonded to either one or both faces. Puncture resistance increased from 101 lbs for the membrane to 136 lbs with a single face bonded, to 214 lbs when both faces were bonded. The friction angle between the membrane and available sandy soils increased from 25 degrees to more than 36 degrees. The resulting composite thus provided a significant increase in both resistance to installation damage and ability to hold cover soil inplace.

During the fall of 1987, a 300 ft square test cover was placed on Site 1A landfill. The geometry and layout of test membranes are shown on Figure 6a. The profile of the cover layer is shown on Figure 6b and consists of the bonded membrane placed immediately on the existing devegetated landfill surface and covered by 12-in of cover soil. Sliding stability calulations indicated that a wide range of soil covers would be stable at slopes less than 2:1. This range of acceptable soils is important since sorces of cover soil are very limited in this region. Additionally, this design included a synthetic drainage composite bonded to the membrane to prevent development of pore pressures that would induce sliding of the cover soil. This drainage composite is manufactured by Monsanto and is commonly used for lateral drains adjacent to highways.

The test membranes were fabricated in 20 ft wide sheets approximately 300 feet in length. The panels were placed down the slope and overlaped approximately 12 in, figure 7. Water tight seams were not made between the panels due to the need for some water infiltration to allow continued methane generation to support a gas mining operation. Due to a drainage canal at the base of the test zone, the cover soil was placed by end-dumping on top of the cap and then pushing this material down-slope with a bulldozer, figure 8. The available cover soil was clayey and rich in both organics and debris. The ability of the bonded membrane to resist excessive puncture damage was very dramatic.

Use of the bonded membrane in place of imported clay did not produce a cost savings in the test but did shorten construction time. Both the prototype nature of the bonded membrane and the small yardage required for the test contributed to a unit high cost for this material. It is expected that increased production and market competition will reduce the unit cost of the composite membrane and lead to a significant cost savings over the clay cap alternative.

Floodwater-Leachate Dike

Flood waters of the Ohio River would annually penetrated the slag heaps generated by a major steel mill. As the flood waters receded, leachate from the slag heaps is drawn into the river and poses environmental problems down stream. Under orders from both

Kentucky EPA and Region 4, the steel mill is required to construct flood walls that prevent the rising river waters from contacting the slag. The general profile of the river bank and slag piles is shown on figure 9. Construction of conventional flood walls is complicated by the presence of significant soft deposits within the river bank. Deep excavations would be very costly and require moving a larger volume of the slag waste.

Several years earlier, we had a similiar project in Kentucky related to protecting a shopping center from annual flooding, figure 10. Detailed cost estimates made in 1985 indicated a conventional sheet pile wall would cost approximately $1.4M for the 3800-ft floodwall. A geotextile wall was eventually constructed at a cost of less than $.5M. A review of conditions at both sites clearly indicated the potential for similiar sayings for the steel mill. A major consideration in the new wall, however, was the extensive review the proposed design would recieve from both state and Region 4 EPA.

A typical section of the final approved floodwall is shown on figure 11. The core of the wall is a double faced fabric wall designed using simple procedures identical to that used for reinforced earth walls (6). The wall is designed to allow the flood waters to saturate the granular fill within the wall without failing the wall. The face of the wall will be coated with a bitumem spray with sand broadcast on the surface. This surface protects the fabric from UV damage and vandalism. Such a surface does require an annual inspection and periodic refreshing. The fabric face has a tensile strength of xxx lb/ft to prevent damage to the face from objects impacting the wall during flooding. The fabric face was actually preferred over a concrete face due to its inherent ductility.

A hydraulic barrier to the rising flood waters will be provided by a membrane attached to the backwall of the dike and keyed into the clayey soils underlying the wall. The membrane itself is protected by a 12 ozsy nonwoven fabric draped over it. Both the membrane and the fabric cover are anchored to the top of the wall using the detail shown on figure 12. A wedge of steel slag will be placed against the membrane-fabric drape to prevent the hydrostatic forces do to the rising floodwaters from simply displacing the membrane laterally.

The proposed environmental dike has been approved by both Kentucky and Region 4 EPA and will be under construction this spring.

Summary

Geosynthetics can provide one of the most flexible building products available to the Civil Engineer for solving environmental problems. The three geosynthetic applications presented here show the significant cost or time savings that are obtained through the innovative application of geotextiles and geomembranes. Beyond economy, many of the polymers used in the manufacturing of these products are highly resistant to chemical attack from contaminants associated with such applications. This combination of economy and chemical resistance makes geosynthetics an important tool in environmental applications.

References

1) Richardson, G.N. and R.M. Koerner, "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments," EPA/600/S2-87/097, EPA, Hazardous Waste Research Laboratory, Cincinnati, Ohio, 1987.

2) Cooper, L.M., "Investigation and Remediation of A Pond Contaminated by Diesel Fuel," ------------

3) Haliburton, T.A., et al,"Design and Construction of a Fabric Reinforced Test Section at Pinto Pass, Mobile, Alabama," Trans. Res. Rec., 1980.

4) Fowler, J.,"Analysis of Fabric-Reinforced Embankment Test Section at Pinto Pass, Mobile , Alabama, Technical Report EL-81-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

5) Proccedings, Very Soft Soil Stabilization Using High Strength Geosynthetics, 1st GRI SEminar, Drexel University, Philadelphia, Pa, Oct. 22-23, 1987.

6) Mitchell, J.K., and W.C.B. Villet,"Reinforcement of Earth Slopes and Embankments," NCHRP Report 290, Transportation Research Board, Washington, D.C., June, 1987.

FIGURES

1 - Photo of contaminated pond - have smashing photo of pond on fire!

2 - Drawing showing divided pond and cross section

3 - Drawing of profile of proposed cap

4 - Drawing showing construction stages

5 - Photo of Meadowlands landfill "mountain"

6 - Drawing of test geometry

7 - Photo of field test of new cover membrane

8 - Photo of dozer placing cover soil on membrane - steep slope

9 - Drawing of river bank and slag pile

10 - Photo of Pykeville, Tenn wall

11 - Drawing of Propose Geosynthetic Dike

12 - Membrane anchorage detail