// What's New in Geo?

ADVANCES IN GEOSYNTHETIC SOLUTIONS FOR SUSTAINABLE LANDFILL DESIGN

Geosynthetics Really *Do* Last!

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Even though geosynthetics are now a well-established discipline within geotechnical engineering, ingenuity continues to play a significant role in projects involving their use. This is because it's possible to tailor the mechanical and hydraulic properties of geosynthetics to address design needs in almost all aspects of geotechnical engineering. Although the ability to achieve consistent geosynthetic properties has been a key consideration since their early use, concerns about their lifespan have subjected geosynthetics to careful scrutiny.

Engineered turf cover installed at Baldwin County Landfill, GA.

Figure 1. **View of stacked geotextile tubes for containment of dredged sediments showing detail of multiple tube operation stages. (Photo courtesy of TenCate Geosynthetics.)**

In recent years, however, there's been increasing confidence within the geotechnical profession regarding geosynthetics' performance and long-term durability. Why? It's because polymer formulations have continued to advance, phenomenal research has been (and continues to be) conducted to quantify the longevity of geosynthetics, and field evidence of good performance has been documented for geosynthetic structures that are more than a half-century old.

This article is not intended to document the important results of recent research on durability or add to an already healthy record of field performance of early geosynthetic structures. Instead, its objective is to illustrate how overcoming early concerns about durability has enabled innovative geosynthetic solutions in landfill design. Geosynthetics have been used in modern landfills in the U.S. for over four decades since the passage of the Resource Conservation and Recovery Act in 1976. Beyond the well-established use of geosynthetics in base liner systems, three relatively new applications are featured in this article that involve the use of geosynthetics as part of the waste disposal, slope stabilization, and final closure of landfills. These applications illustrate recent advances in geosynthetic solutions to overcome enduring challenges previously managed using traditional approaches.

Stacked Geotextile Tubes for Waste Disposal

The use of geotextile tubes combines dewatering and disposal of industrial wastes, such as sludges, dredged sediments, and sluiced coal combustion residuals (CCR), into one operation, significantly reducing the handling of saturated wastes. Geotextile tubes involve high-strength, permeable woven geotextiles sewn into a tube. When used for dewatering, the geotextile acts as a filter that allows water flow while retaining the solids in the tube. The dewatering process includes three main stages: hydraulic filling, free water drainage, and consolidation (Figure 1). Flocculants are usually added to fine-grained slurries to facilitate agglutination of solid particles. After dewatering is complete, geotextile tubes can be either transported for off-site disposal or capped in place for permanent disposal. Unlike traditional dewatering techniques, such as settling basins, geotextile tubes offer high dewatering efficiency and provide effective odor control by limiting exposure of waste to air.

A recent trend in geotextile tube applications involves stacking them in multiple layers to reduce the disposal area footprint in large environmental remediation projects. For example, as part of the Onondaga Lake Cleanup Project near Syracuse, NY, about 1.6 million m^3 of contaminated sediments dredged from the lake were dewatered and contained using approximately 1,000 geotextile tubes that were up to 91 m in length and 24-27 m in circumference. The geotextile tubes were stacked in six layers approximately 11 m high within the 22-hectare landfill footprint and permanently capped in place with a soil-geosynthetic final cover in 2017. Figure 1 shows an aerial photo of the stacked geotextile tubes during construction. The key design considerations when stacking geotextile tubes include internal stability of individual tubes, slope stability of stacked tubes, and settlement and bearing capacity of the foundation that supports stacked tubes.

Another trend is to utilize the waste encapsulated in the geotextile tubes as fill material to reduce the quantity of imported construction materials. A geotextile tube wall was constructed in 2016 during closure of an ash pond at a large Mid-Atlantic utility site. The wall separated the ash pond into a pool section that continued to serve as an operations area to receive sluiced CCR, and a construction section where preparation work for final closure grading was to be started. The geotextile tubes were stacked in two layers and formed an approximately 18- to 24-m-wide, 3.4-m-high, and 730-m-long wall. Approximately 61,000 m^3 of in-situ fly ash were dredged and pumped into the geotextile tubes and used as the fill material to construct the wall. Figure 2 shows a section of the installed geotextile tube wall.

Durable Geosynthetic Reinforcements for Waste Containment Stabilization

While many design solutions have been adopted to maximize the available waste capacity within the defined footprint of landfills (e.g., dynamic compaction, bioreactor technology, and landfill mining), the use of geosynthetic-reinforced structures, such as mechanically stabilized earth berms, has been incorporated into landfill designs over approximately the last two decades. While the design of reinforced-soil structures generally requires granular backfill material, landfill owners have started using actual landfill waste as backfill material to optimize the site geometry and reduce construction costs.

The use of waste as backfill material introduces several challenges into the design of the reinforced-soil structures. Geotechnical properties of municipal solid waste are inhomogeneous and highly depend on the composition of the waste itself — in particular, the percentage of organic components that decompose over time. Furthermore, waste degradation involves complex fermentation phenomena, chemical alteration, creep, oxidation, and cementation that results in mineralization of the waste. The resulting waste often has an average temperature of 40° C, with peaks over 60° C

Figure 2. View of geotextile tube wall filled with re-used fly ash in an ash pond at a Mid-Atlantic utility site. (Photo courtesy of TenCate Geosynthetics.)

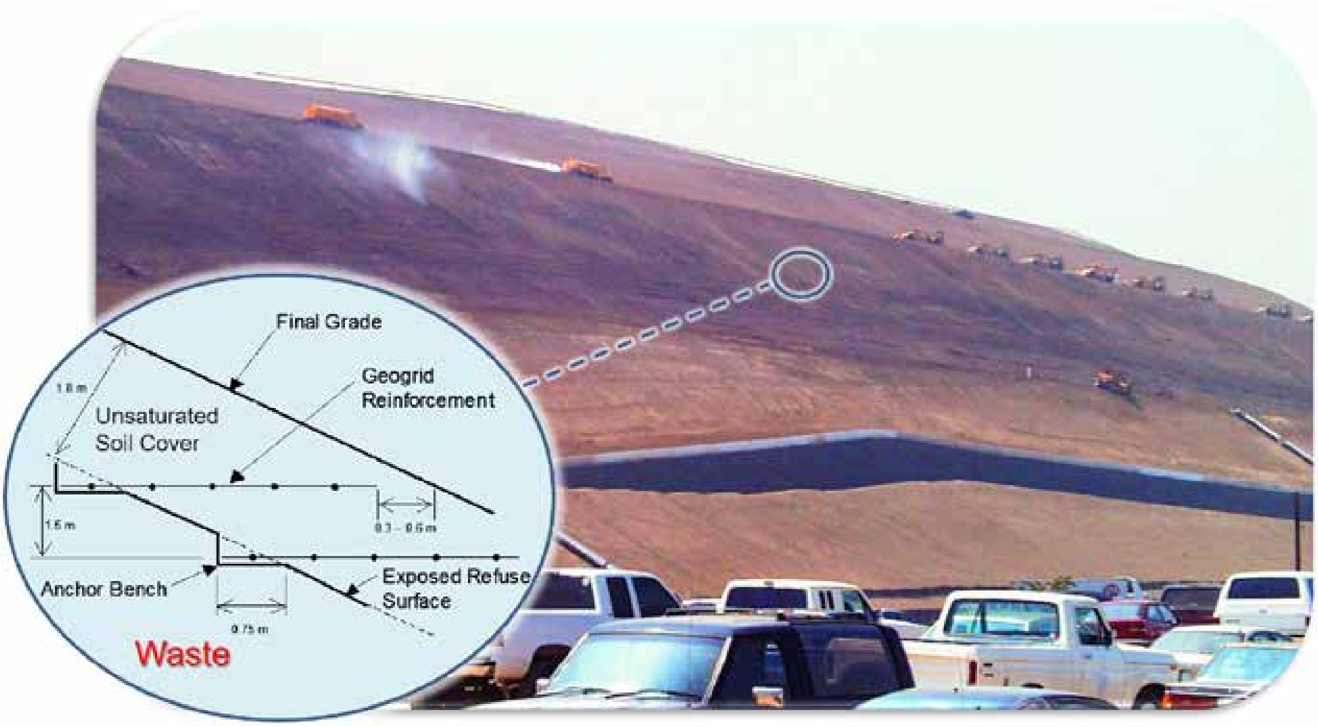

Figure 3. View of a geogrid-reinforced soil cover system on the North Slope of the OII Superfund Landfill. Note the detail of the geogrid reinforcements anchored into solid waste.

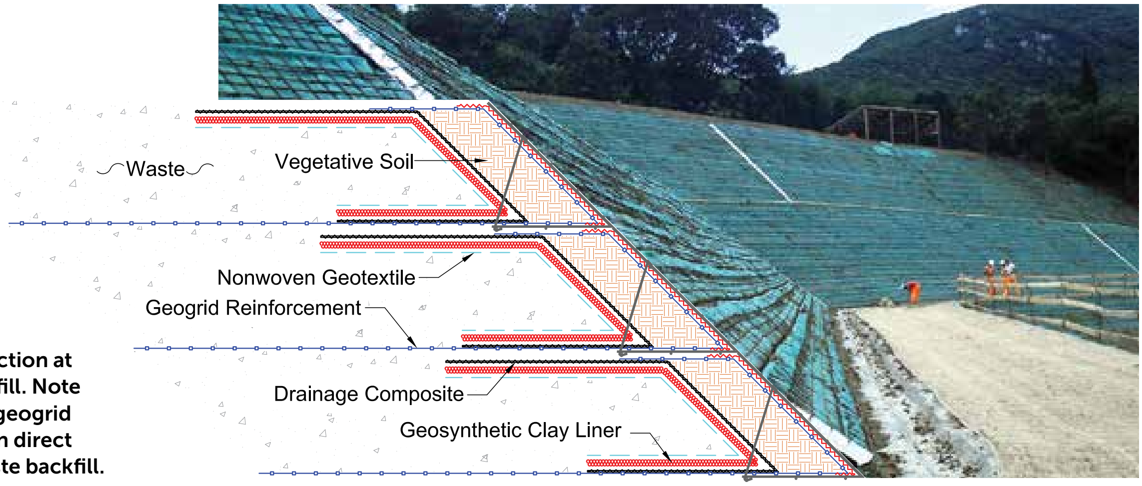

Figure 4. View of capping cross section at Niccioletta Landfill. Note the detail of the geogrid reinforcements in direct contact with waste backfill.

due to anaerobic digestion, and is often chemically aggressive. Key aspects to be considered when selecting geosynthetic reinforcements, such as geogrids, include their resistance to chemical degradation under a wide range of pH, creep performance, performance at high temperatures, and resistance to mechanical damage during waste compaction.

The final closure of the Operating Industries, Inc. (OII) Superfund Landfill located near Los Angeles, CA, is an early design example involving geosynthetic reinforcements in direct contact with solid waste. One of the most challenging design and construction features of that project is related to the stability of the landfill's North Slope. The North Slope is located immediately adjacent to the busy Pomona Freeway. It rises up to 65 m above the freeway and consists of slope segments separated by narrow benches that are as steep as 1.5H:1V and up to 30 m high. As illustrated in Figure 3, horizontally placed uniaxial geogrids anchored in the actual solid waste were selected as the most appropriate and cost-effective method for stabilizing the engineered soil cover constructed over the North Slope. The cover has performed well since its construction over 20 years ago, which demonstrates that the geosynthetic reinforcement solution has been both durable and successful.

In 2011, a landfill cell was constructed in Niccioleta, Tuscany, Italy, using waste as fill material for the reinforced side slope (Figure 4). A geogrid material was used to reinforce each layer of waste material, providing the tensile strength required to achieve internal stability. Additionally, two layers of drainage geocomposites and one layer of geosynthetic clay liner were wrapped around each layer of waste to form the landfill's final capping system. A layer of vegetative soil, retained by a turf-reinforcement mat, was subsequently placed in the slope face to provide a vegetated facia and an extra layer of protection for the capping system. As designed, the system allowed the construction of landfill cells having side slopes at angles much steeper than the typical 3H:1V slope, significantly increasing the overall landfill cell capacity.

Engineered Turf Cover for Final Closure

Closure of a landfill is required after reaching final grades to isolate the underlying waste and manage long-term environmental risks. Traditionally, landfills have been closed using soil covers with geosynthetic components. A traditional landfill cover, for example, consists of (from bottom to top) a geomembrane barrier layer, a geocomposite drainage layer, and a protective/vegetative soil layer that is at least 0.6 m thick. Two persistent, long-standing challenges associated with many traditional soil covers are soil erosion and cover slope failures.

The engineered turf cover is a relatively new landfill closure solution that uses engineered turf and a specified infill to replace the protective/vegetative soil layers used in traditional soil covers. The elimination of these soil layers removes soil erosion as a driving force behind cover slope failures. Because engineering turf is not susceptible to erosion, it's less affected by factors such as changing weather conditions and varying soil properties compared to traditional soil covers. Moreover, engineered turf covers require less post-closure maintenance because soil-erosion repairs, re-vegetation, fertilization, mowing, and stormwater pond cleaning are not needed.

The engineered turf component is made of high-density polyethylene (HDPE) synthetic grass blades tufted into a double-layer polypropylene, woven geotextile backing, which is placed directly on top of a HDPE or linear low-density polyethylene-structured geomembrane (Figure 5). The specified infill, either bonded or unbonded clean sand with a minimum layer thickness of 13 mm, is placed inside the synthetic grass blades. The engineered turf and infill function primarily to protect the geomembrane from ultraviolet (UV) exposure, wind uplift, and puncture by external forces, such as vehicular traffic, hail, and animals.

The first engineered turf cover was installed in 2009 at a four-hectare MSW landfill in Louisiana to solve recurrent soil-erosion problems. In 2013, installation of a 28-hectare engineered turf cover was completed at the Crazy Horse MSW Landfill in California; it was selected to meet the design requirements of final cover stability for both static and seismic conditions for steep side slopes up to approximately 2H:1V. To date, engineered turf covers have been or are being installed at more than 40 sites in over 20 states in the U.S., covering a total area of more than 600 hectares. These sites include MSW landfills, industrial waste landfills, and CCR landfills and surface impoundments. Figure 5 shows the aerial photo of a 14-hectare engineered turf cover installed in 2014 at the Hartford Landfill in Connecticut.

Sustainability for landfill closures entails long-term performance and minimal environmental and social impacts. The design life of the engineered turf cover is projected to be over 100 years as a result of the enhanced UV stabilization of the synthetic turf fibers. The carbon footprint of engineered turf cover is smaller than that of traditional soil covers due to faster installation, fewer construction materials, fewer construction equipment operations, and less post-closure maintenance. In addition, land disturbance is avoided because borrow soils are not needed, which results in less impact on local communities as a result of less truck traffic on local roads.

Engineered turf covers also facilitate reuse of the large space at the top of landfills after closure, such as converting them into a solar farm because maintenance of grass within the array isn't needed. Figure 5 shows the 1-megawatt solar-electricity-generating facility installed atop the Hartford Landfill, which powers approximately 1,000 homes per day at peak capacity. The solar array is supported by a racking system ballasted with concrete blocks that sits directly on the engineered turf cover. This approach reduces maintenance, because the solar panels are not subject to potential damage from mowing equipment and the runoff from the drip edge of the solar panels does not induce soil erosion that would undermine the panel foundations. Additionally, the engineered turf cover provides a relatively dust-free environment that promotes efficient solar collection.

Looking Ahead

Advances in geosynthetics have made these materials a well-established technology within the portfolio of solutions available to geotechnical engineers. The old question, "How long will they last?" is being addressed through extensive research, sound engineering design, and innovative applications. This contributes to sustainable landfills by incorporating geosynthetics in the design of landfill components related to disposal operations, stabilization approaches, and final closure systems, as illustrated in the three applications presented in this article.

Innovative geosynthetic materials, products, and designs are expected to continue to emerge with the pursuit of sustainable designs. For example, according to data provided by the U.S. Environmental Protection Agency, there are more than 1,000 active CCR landfills and surface impoundments in the U.S. that require closures, creating opportunities for implementing new geosynthetic solutions. Overall, geosynthetics play an important role in geotechnical projects in general and landfill design in particular because of their versatility, cost-effectiveness, ease of installation, and good characterization of their mechanical and hydraulic properties. The creative use of geosynthetics in geotechnical practice will continue to expand as manufacturers continue to develop new and improved materials, and engineers come up with new design approaches and field applications.

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Figure 5. View of engineered turf cover installed at Hartford Landfill showing detail of the different components of the cover.