Geocellular-Stabilized Covers over Geomembranes

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Economic pressure, the desire for green solutions, and the intensification of climate extremes have converged to create a need for better methods to effect soil stabilization. Fortunately, a proven technology exists that addresses issues associated with these conditions and provides a more stable cover solution for landfill covers, lagoons, storm water containment basins and other geomembrane covered systems. Soil, aggregate and concrete protective covers over geomembranes can be secured against known gravitational, hydrodynamic and seismic forces using a geocellular confinement system.

Soil and aggregate are commonly used as a protective cover over geomembranes on slopes of 3H:1V or less. When slope gradients are greater than 3H:1V, soil and aggregate covers are typically unstable and not used. In arid areas, cover depth may range from 75 mm (3 in) to 150 mm (6 in). In climatic conditions that support vegetation, cover depth may range from 150 mm (6 in) to 600 mm (24 in) or greater where the final depth is a function of the characteristics of the desired vegetation. Regardless of cover depth, if an extreme rainfall event occurs that is 10%, 20%, or 30% greater than what would typically be expected, soil mass increases, assumed friction angles decrease, and factors of safety for soil stability drop to a point where failure of the cover occurs and exposure of and/or damage to the geomembrane results.

A typical unconfined soil cover that failed, when exposed to heavy rains and its subsequent repair with the Presto Geoweb® cellular confinement system, is illustrated on the residue disposal area at a pulp paper mill in Bahia, Brazil.

For many years, the mill dumped eucalyptus trunks and bark, lime, contaminated soils and other waste on the site creating a large pile of environmentally-damaging materials.

Pressure from regulatory agencies as well as obvious environmental issues, motivated the mill to take action.

The stated objectives for the remediation were:

- to prevent rain and wind dispersion of residues and contaminants,
- to prevent infiltration of contaminants into the aquifer,
- to prevent contaminated residues from coming in contact with personnel and animals, and
- to develop an aesthetically-pleasing landscape.

The residue dumpsite in 2003.

A solution was then developed considering the four stated objectives as well as considering the future need to use the dumpsite for additional waste.

ORIGINAL REMEDIATION

The remediation work started in late 2005, with the re-grading of the residue to a stable slope of 3H:1V. This slope-grade also guaranteed the stability of the residue and allowed for the placement of additional waste on top of the existing residue.

After the earthwork was completed, confinement work began in January 2006. First, a gas collection system was installed. Next, a 1.5 mm (60 mil) thick, textured, high-density polyethylene (HDPE) geomembrane was installed. A 200 g/m^2 (6 oz/yd^2) nonwoven geotextile was installed over the geomembrane as a protection layer and subsequently covered with 0.60 m (24 in) of soil. Within the soil cover, a subsurface drainage system was installed for removal of infiltrating rainwater. The drainage system used 100 mm (4 in) diameter perforated PVC pipe installed directly over the geotextile 10.0 m (33 ft) on center allowing the groundwater to pass through the pipe collection system and discharge into a surface channel at the toe of the slope.

Residue dumpsite being graded.

FAILURE OF THE SOIL COVER

In this region of Brazil, the rainy season starts in April and typically lasts to September. Heavy rain may also occur in other months. In mid-June 2006, after a heavy rainfall, the soil cover on the 3H:1V slope failed at the geotextile-geomembrane interface and a large volume of soil slid down the slope from crest to toe. Furthermore, at some locations along the slope-crest, the geotextile tore, exposing the geomembrane.

The failed original slope cover viewed from the crest of the slope down.

Damaged geotextile resulting from slope failure.

Contributing factors to the slope cover failure were (1) a relatively low, (however within acceptable norms), interface friction angle between the geotextile and the textured geomembrane, (2) increased load from the saturated soil, and (3) seepage forces due to water flow within the relatively thick soil cover layer. The failure involved 1,200 m^3 (12,900 ft^2) of cover soil and 1,800 m^2 (19,400 ft^2) of geotextile. Although the geomembrane was not yet affected by the tear in the geotextile, a repair was urgently needed to prevent damage.

COVER REPAIR WITH A GEOCELLULAR SYSTEM

After complete analysis of the failure, several alternatives were considered for the repair. However, use of the Geoweb slope cover system best addressed all critical details. The following parameters were considered critical for the redesign of the soil cover system:

(1) slope heights from 20 m (66 ft) to 35 m (115 ft),

(2) a 3H:1V (18.4°) slope angle,

(3) a critical interface friction angle between the sand and geomembrane of 15°,

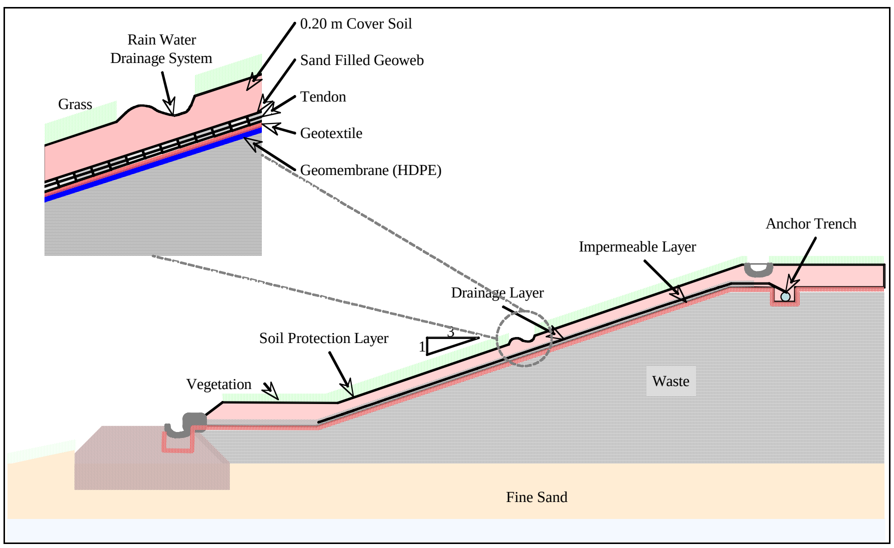
(4) a total slope soil-cover of 60 cm (24 in),

(5) a cover anchoring system to resist all potential loading,

(6) a self-sustainable vegetated cover,

(7) the need for a drainage system that would quickly drain extremely saturated soil, and

(8) long-term functional life.



New covering system using the sand-infilled Geoweb system.

The new cover consisted of a sand-infilled, perforated Geoweb drainage layer installed directly over the textured HDPE geomembrane. The cell depth of the Geoweb layer was 75 mm (3 in). In areas where the original geotextile had not failed, the Geoweb sections were installed directly over that geotextile layer. The use of a sand drainage layer provided two benefits: (1) Increased friction angle at the critical interface with the geomembrane; and (2) Provision of a critical system drainage layer. In some areas, due to the characteristics of the final 53 cm (21 in) depth topsoil layer, a 200 g/m^2 (6 oz/yd^2) nonwoven geotextile filter/separation layer was placed over the sand-infilled Geoweb layer. In other areas this geotextile layer was not used because the final soil cover had characteristics compatible to the sand drainage layer.

Installation of the perforated Geoweb® sections over the textured geomembrane.

The Geoweb sections were structurally anchored at the slope crest using high-strength polyester tendons with a long-term design strength of 13.3 kN (3,000 lbf). The required strength considered the fully covered and saturated soil mass over and in the Geoweb sections. For the 35 m (115 ft) long slopes, the analyses determined that five polyester tendons per Geoweb section were required. Tendons were secured to a 100 mm (4 in) diameter pipe deadman buried 0.48 m (18 in) below the final grade at the crest of the slope. The tendon strength design factor-of-safety was 5.0 and it included partial factors of safety for creep, knots, constructions damage, chemical and biological durability and overall uncertainties. All present and potential sliding forces within the Geoweb system were transferred to the tendons by means of special load transfer ATRA® clips at required downslope intervals. Proper design analyses to determine tendon and load transfer requirements as well as geocell seam strength are critical factors to the overall long-term performance of the cover system.

Tendoned Geoweb sections installed and ready for sand infill.

During construction, the tendoned and perforated Geoweb material provided a stabilizing “formwork” that prevented sand flow during installation during rainfall as well as allowing for rapid drainage of the saturated sand infill. The tendoned Geoweb system is a unique way to create a structurally-stable sand drainage layer directly over a geomembrane.

Infilling the Geoweb system with sand.

View of the area with residue being placed on top of the new system.

RESULTS OF THE COVER REPAIR

Construction work took place from October to December of 2006. The system has been through the 2007 and 2008 rainy season and has performed exceptionally.

Completed vegetated cover solution.

Technological advancements provide us with improved methodologies and materials so that sustainable, long-term solutions can be developed with some of the most challenging situations. The Geoweb system proved to be a technically sound, low environmental impact solution with high cost-benefit for this project..

Original paper entitled, "Failure of a Landfill Cover and Remediation using Geocells" was presented at the First Pan American Geosynthetics Conference & Exhibition, March 2008, Cancun, Mexico. Original paper was co-authored by Mauricio Abramento, PhD, CEG Engenharia, Marcos Mello Rocha Campos, MSc, GEOKLOCK Consulting and Environmental Engineering, Claudia Vasquez Bastias, Fiberweb Bidim and Daniel Senf, PE, CPESC, Presto Geosystems.